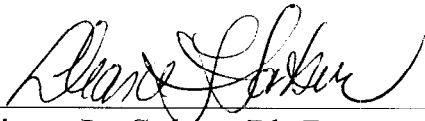


IGT Project Number: 40800-01

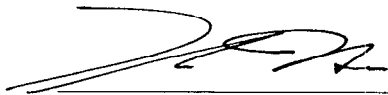
COMPARATIVE ANALYSIS OF NAPL RESIDUES FROM
THE NSP ASHLAND FORMER MGP SITE AND THE
ASHLAND LAKEFRONT PROPERTY (KREHER PARK)

Prepared by

INSTITUTE OF GAS TECHNOLOGY
1700 South Mount Prospect Road
Des Plaines, Illinois 60018



Diane L. Saber, Ph.D.



Thomas D. Hayes, Ph.D.

For

NORTHERN STATES POWER COMPANY
100 N. Barstow Street
Eau Claire, Wisconsin 54702-0008

February, 2000

EXECUTIVE SUMMARY

The Institute of Gas Technology has conducted a comparative study of nonaqueous phase liquid (NAPL) samples collected from the Northern States Power Company former manufactured gas plant facility (MW-15), the Copper Falls aquifer (EW-1) and the Ashland Lakefront Property (Kreher Park, MW-7) in Ashland, Wisconsin. Samples were tested and evaluated against known standards for similarities and dissimilarities in tar composition and in quantity (percent content) of middle weight petroleum distillates (fuel oils). A literature search was performed to further corroborate results of testing with typical industry standards for identification of the NAPL samples.

Using GC/FID fingerprinting techniques, results concluded that NAPL material from MW-15 and EW-1 are very similar in tar composition, both exhibiting a pattern typical of carburetted water gas (CWG) tars. The composition of samples MW-15 and EW-1 are also highly similar in the small percentage of middle weight petroleum distillates (average 8 percent aliphatic component). These samples are likely from the same source. This result is consistent with the fact that EW-1 is directly below the former MGP facility and may have been affected by site operations.

Sample MW-7 is distinctly different from samples from MW-15 and EW-1. Sample MW-7 contains an MGP-type tar and a substantial fraction of middle weight petroleum distillate. The tar from MW-7 does not exhibit a pattern typical of the CWG standard. Nearly 30 percent of the sample from MW-7 is middle weight petroleum distillate; this is significantly greater than the percentage of middle distillate fraction of residues in samples from MW-15 and EW-1. Data indicate that the MW-7 NAPL is derived from a source separate from that of samples derived from MW-15 and EW-1, and that the sample from MW-7 may represent an intentional mixture of petroleum-derived material and tar.

Middle petroleum distillates may include diesel fuel, #2 fuel oil, gas oil and other fuel oils and were typically used as carriers in wood treatment operations. Material found in MW-7 is consistent with the US EPA definition of a wood treating mixture, "consisting of 35% by weight aliphatic hydrocarbon (oil) and 65% by weight polynuclear aromatic".

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INTRODUCTION

Northern States Power Company (NSP) has contracted the Institute of Gas Technology (IGT) to determine whether nonaqueous phase liquid (NAPL) residues found in wells located on or below their Ashland former manufactured gas plant (MGP) site are chemically similar or dissimilar to the NAPL residues found in a well located in the area of former wood treatment operations in Kreher Park. IGT has performed a series of highly definitive, defensible tests designed to answer the question of whether the MGP residues found in wells MW-15 and EW-1 are similar to NAPL material found in Kreher Park (MW-7).

IGT and its subcontractor (META Environmental, Inc.) have completed forensic analysis of three NAPL samples. Analyses of these samples have included identification and/or quantification of: 1) monocyclic hydrocarbons (MAHs), 2) polycyclic aromatic hydrocarbons (PAHs), and, 3) aliphatic hydrocarbons and polar hydrocarbons. Analyses and hydrocarbon fingerprinting were performed using gas chromatography with flame ionization detection (GC/FID).

The GC/FID method of analysis is routinely used to identify specific compounds present in a sample, which can then be compared with a "standard" sample of known origin or composition. The GC/FID analysis does not quantify the compounds found in the mixture. Results obtained from a single GC/FID scan show the FID detector response versus residence time of each compound in the chromatographic column. The pattern of peaks versus residence time that is generated in the GC/FID scan is sometimes referred to as the "fingerprint" of the sample. In this way, an investigator may "fingerprint" the sample by comparing scan features of the test sample with scan features of a control sample. For instance, particular relative ratios of one compound to another, the relatively high concentration of a compound or the absence of particular compounds may be indicative of a carburetted water gas tar, a high temperature coal tar or a mixture of alternate origin. Generally, several identified reference samples are used when conducting the GC/FID analysis, so that the test sample may be compared with accuracy.

In order to quantify the compounds or classes of compounds contained in the sample mixture, the sample is then subjected to a second set of analyses. This analysis (a form of distillation) determines total extractable hydrocarbons, total aliphatic hydrocarbons (middle range distillates) and total aromatic hydrocarbons (tars). Using this procedure, the actual percentage of middle range distillate versus the tar fraction in the whole sample may be determined. This analysis is key in identifying the *type* of mixture present in the sample.

The NAPL samples were collected from wells located on the former Ashland MGP site (MW-15), from the Copper Falls aquifer (EW-1), directly below the former MGP site, and from a well located in Kreher Park (MW-7) that is within an area reportedly occupied historically by wood treatment operations. The purpose of these tests was to determine chemical similarity or dissimilarity between all samples and to determine exact composition of the samples. Results of these analyses are included in this report, with expanded analytical data detailed in Appendix A.

SITE BACKGROUND

The NSP Former MGP Site

Northern States Power acquired property located on Lake Shore Drive in Ashland, Wisconsin. The Lake Shore Drive facility lies approximately 1,000 feet southeast of the shore of Chequamegon Bay of Lake Superior and was formerly held as an MGP operation. The former MGP operated predominantly as a manufacturer of water gas and carburetted water gas between 1885 and 1947. Oil gas was the likely feedstock during this period. For a brief time in 1917, the Lake Superior District Power Company (LSDP) reported the production of coal gas, comprising less than 15 percent of that year's output. However, no other coal gas production at any other time has been reported.

Coal tars were produced in the process of gas manufacturing. Only three years of data is available concerning the disposition of this material. However, operating records from those years indicate that, in addition to being burned on site for energy recover, much of the tar was sold.

The site is currently occupied by a small office building, a vehicle maintenance building and parking lots. The area is relatively flat, at an elevation of approximately 640 feet above mean sea level. A ravine historically ran north across the site from Lake Shore Drive, and opened onto the Lakefront at the bluff overlooking the bay. Historic Sanborn Fire Insurance maps (Sanborn Maps) indicates the ravine was filled from south to north over time. By 1909, the entire ravine was filled with low permeability, mixed fill, consisting of clays, cinders and rubble. Monitoring Well-15 (MW-15) is located on the NSP former MGP site, immediately adjacent to the present-day vehicle storage building. Well MW-15 was installed to the base of the backfilled ravine, at a depth of 17 feet bls, and screened between 5 and 15 bls. The ravine is underlain by the cohesive Miller Creek formation, a clayey-silty unit that, for the area north of St. Claire St., creates a confining aquitard for the underlying Copper Falls formation aquifer. (1) The ravine fill area and associated shallow, perched groundwater has been termed Operable Unit-1 (OU-1).

The Copper Falls formation is an artesian aquifer in the NSP site area, and underlies the Miller Creek formation. The Copper Falls aquifer consists of interbedded clays, sands and gravels. The lithologic change in the Miller Creek south of St. Claire St. has allowed the vertical (downward) migration of coal tars into the Copper Falls aquifer. The upward gradients in the Copper Falls have "forced" contaminants (DNAPLs) upward with the general northward flow of groundwater in this aquifer. Consequently, a mushroom-shaped plume is present in the Copper Falls below the NSP site. Extraction Well-1 (EW-1) is located on the NSP former MGP property, adjacent to St. Claire St. and just west of the present-day vehicle storage building. It was installed to a depth of 56 feet bls, within the Copper Falls aquifer, and screened 35-55 bls. The Copper Falls aquifer unit has been termed Operable Unit-2 (OU-2) (1, 2).

The Ashland Lakefront Property

The Ashland Lakefront Property site includes the area defined by Kreher Park and the adjacent bay sediments. This area is bounded by Prentice Avenue and a jetty extension of Prentice

Avenue to the east, the Wisconsin Central Limited (WCL) railroad to the south, Ellis Avenue and the marina extensions of Ellis Avenue to the west, and Chequamegon Bay to the north. The affected sediment area is a confined inlet created by the jetty and marina extensions.

The Kreher Park area is reclaimed land of which the south boundary defined the original lake shoreline. Beginning in the mid to late 1800's, the area was filled with a variety of materials including slab wood, concrete, demolition debris, municipal and industrial wastes and earth fill that created the land now occupied by the park. Kreher Park area was constructed to create land for the lumber operations that subsequently followed at the site. Several lumber operations occupied the property, but the largest facility and longest tenured was the John Schroeder Lumber Company. Schroeder Lumber occupied the site from 1901 until 1939, when Ashland County took title to the site and sued to eject Schroeder. Schroeder's operations were extensive. Schroeder's "articles of incorporation" stated that one of the company's business purposes was to: "...manufacture and deal in preservative chemicals, to own and operate wood preservation plants and plants for the manufacture and stillization of wood-byproducts, to explore and develop lands for gas, minerals, ores and oils, and to collect, work, use, and treat any timber and all forest and other vegetable products." Based on research performed by NSP, Schroeder's Ashland plant was the company's only wood processing facility. Schroeder's Ashland Sawmill/Wood Processing facility was described as, "one of the largest and best equipped mills in the greater northwest." Details of the Schroeder operation, including the physical location of facility appurtenances, were obtained from interviews of eyewitnesses, review of historic documents, as well as fire insurance (Sanborn) maps. This information indicates that an above-ground structure or structures used for creosote dipping or treatment of railroad ties, telephone poles and the like was located in the west-central area of the present Kreher Park. Additionally, oil houses associated with Schroeder's operations were located in the east central part of Kreher Park as shown on Sanborn Maps.

Following Schroeder Lumber's tenure, Ashland County transferred title to the City of Ashland in 1942, which has owned the site since. During some time in the 1940's and 50's, the City operated a portion of the site in the present northwest area as a waste disposal facility (landfill). In 1951, the Wastewater Treatment Plant (WWTP) was constructed and operated as the City's sewage treatment facility until 1989. During exploratory work to expand the WWTP into the Kreher Park area in 1989, soil and groundwater contaminated with creosote/coal tar compounds were encountered. The City notified the Wisconsin Department of Natural Resources (WDNR). The WDNR authorized SEH to initiate an investigation and evaluation of the area to characterize the extent of contamination at the site, which heretofore had been referred to as a creosote contaminated site. (3).

The SEH investigation of groundwater in the Kreher Park area revealed that a variety of organic contaminants were present. Well MW-7 is located in Kreher Park, among a set of wells within the former wood treatment location, at the base of the ravine and at the groundwater/surface water interface. Well MW-7 is installed to a depth of 15 feet bbs, and is screened between 5 and 15 feet bbs. Free product in the well appears to be a dense, black, oily DNAPL hydrocarbon. The DNAPL measured in this and one other well may correspond to a pool of product related to the former wood treatment area labeled as a "waste tar dump" on Greeley and Hansen 1951 WWTP drawings. This depicted area is in the same general location that several eyewitnesses

identified a man-made aboveground structure used for Schroeder Lumber's wood treatment operations. Black tar deposits on soil samples excavated from test pits in this area may indicate the general location of wood treatment activities. Kreher Park has been termed Operable Unit-3 (OU-3) and the near-shore sediments have been termed Operable Unit-4 (OU-4). The near-shore sediments have not been discussed as part of this work product (3).

METHODS

Dense, non-aqueous phase liquid (NAPL) samples were collected from wells located on the former Ashland MGP site (MW-15), from the Copper Falls aquifer (EW-1) directly below the former MGP site, and from a well located within the area of former wood treatment operations in the lower ravine, in Kreher Park (MW-7). Samples were collected from monitoring wells MW-7 and Mw-15 on November 9, 1999, and shipped to the laboratory the same day. The EW-1 sample was collected on November 16, 1999, and sent to the laboratory at a later date. Disposable bailers were used to collect each sample. Each bailer was slowly lowered to the bottom of the monitoring well and slowly removed from the well. A bottom discharge device was used to place the DNAPL in clear glass 40 ml VOA bottles with septum seals, packaged in ice and sent with the completed chain-of-custody forms by overnight mail to the laboratory (META Environmental, Inc., Watertown, MA) for immediate analysis. The results of the analyses are included in this report, with expanded analytical data detailed in Appendix B.

Analyses of these samples included: 1) gas chromatography with flame ionization detection (GC/FID), and, 2) simulated distillation. A chromatographic fingerprint was obtained from each sample using GC/FID, identifying and/or quantifying each of the compound classes: 1) monocyclic hydrocarbons (MAHs), 2) polycyclic aromatic hydrocarbons (PAHs), and, 3) aliphatic hydrocarbons and polar hydrocarbons.

RESULTS

The GC/FID fingerprint data from the three samples show that the NAPL residue of the former wood treatment operations in Kreher Park (MW-7) is significantly dissimilar to the fingerprints of the NAPL samples taken from the NSP former MGP site area (MW-15 and EW-1). Particular observations drawn from the results are as follows:

- The GC/FID fingerprints of the whole extracts of the samples from MW-15 and EW-1 are very similar. These samples exhibit characteristics of many former MGP tars. Based on these data and in comparison with samples of known origin, samples from MW-15 and EW-1 have been identified as carburetted water gas tars, and are likely from the same source.
- The GC/FID fingerprints of all fractions of the sample from MW-7 are distinctly different from those of samples from MW-15 and EW-1.
- When compared with standard samples of known origin, the sample from MW-7 does not exhibit the characteristics of a carburetted water gas tar.
- The GC/FID fingerprint of the sample from MW-7 indicated a greater fraction of the sample consisted of aliphatic hydrocarbons (middle petroleum distillate fraction) than in the fingerprints of samples from MW-15 and EW-1. The GC/FID fingerprint indicates that sample from MW-7 is a mixture of tar and middle petroleum distillates.
- Results from the simulated distillation of the sample from MW-7 indicates that the percentage of aliphatic hydrocarbons (middle petroleum distillates) is substantially higher than in samples from the former MGP site (MW-15 and EW-1). The aliphatic hydrocarbon composition of the sample from MW-7 was nearly 30 percent of total, versus an average 8 percent for samples from MW-15 and EW-1.
- Distillation results further showed that the aromatic composition of the sample from MW-7 was markedly different from the former MGP site samples. The aromatic composition of the sample from MW-7 was 65 percent of total, versus an average of 86 percent from the former MGP site samples, MW-15 and EW-1.

The actual GC/FID scans or fingerprints for each sample and corresponding controls (standards) are shown in Appendix B.

DISCUSSION OF RESULTS

Results of all testing indicated the following:

- 1) Samples from wells MW-15 and EW-1 are highly similar and appear to be derived from the same source. They are both carburetted water gas tars. This result is consistent with the fact that EW-1 is directly below the former MGP facility and was affected by site operations. The NSP Ashland former MGP operated predominantly as manufacturer of water gas and carburetted water gas between 1885 and 1947 (1).
- 2) The MW-7 NAPL is substantially dissimilar to NAPL from MW-15 and EW-1. Compared with known standards, it is not identified as a carburetted water gas tar.
- 3) The quantity (percentage) of aliphatic compounds in MW-7 is strikingly different from MW-15 and EW-1 samples. Nearly 30% of the MW-7 sample is middle petroleum distillate, with ~~70%~~ ^{65%} being aromatic (tar), while only an average of 8% aliphatic compounds (~~92%~~ ^{76%} aromatic) are contained in samples from MW-15 and EW-1. The sample from MW-7 appears to represent an intentional mixture of petroleum-derived material and tar. Material found in MW-7 is consistent with the US EPA definition of a wood treating mixture: "consisting of 35% by weight aliphatic hydrocarbon (oil) and 65% by weight polynuclear aromatic" (4). These results are consistent with the fact that sample MW-7 was retrieved from a well located in Kreher Park, documented as the location of a known wood treatment operation (3).
- 4) Middle petroleum distillates are comprised of diesel fuel, #2 fuel oil, gas oil and other fuel oils. It is well known that petroleum distillates were typically used as carriers in wood treatment operations (5). The above described results are consistent with the fact that MW-7 is located within Kreher Park, near the "waste tar dump", in an area separate from and with no geological connection to the former MGP site. Kreher Park was the location of known wood treatment operations during the years 1901 to 1939 (3).

CONCLUSIONS

Results of testing and analysis of samples retrieved from wells MW-15 and EW-1 are conclusive and predictable. The DNAPL material from these wells is highly similar in composition. Based upon critical analysis and interpretation of these samples against known standards, it is clear that these samples are both carburetted water gas tars and appear to be derived from the same source. This result is highly consistent with the fact that EW-1 is directly below the former MGP facility and was affected by site operations. The NSP Ashland former MGP operated predominantly as manufacturer of water gas and carburetted water gas between 1885 and 1947 (1).

Testing and analysis of the DNAPL sample retrieved from well MW-7 is also conclusive. When directly compared with samples retrieved from wells MW-15 and EW-1, it is evident that the sample from well MW-7 is from a separate source. The well MW-7 NAPL is significantly dissimilar to NAPL from MW-15 and EW-1. Compared with known standards, it is not identified as a carburetted water gas tar.

The wood treatment industry used a wide variety of mixtures of organic-based wood preservatives throughout time (6). Tar-derived, or creosote-type, wood preservatives are among the oldest industrial wood preservatives, with usage dating back some 150 years. Creosote is a petroleum product obtained by the fractional distillation of crude coal tars. The preservative is a blend of hundreds of compounds distilling over the range of 200-400°C, with constituent makeup varying and dependent on the source of coal used for production (5). More than 400 individual compounds can be identified in any creosote mixture.

The specifications for creosotes for timber preservation have changed throughout time. Creosote specifications have developed progressively, largely as a result of varying requirements of the product based upon the type and quantity of material treated. Generally, the nature of a particular creosote depended on the type of coal tar used and the nature of the distillation process, so that individual local specifications tended to be concerned largely with the control of the available product. Coal-tars from a variety of sources were often co-mingled and reprocessed into the final wood treatment product. It was only in 1936 that the International Advisory Office of Wood Preservation in The Hague arranged a conference in Copenhagen to agree on specifications for use by Scandinavian purchasers. The United States American Wood Preservers' Association began to develop specifications also at about the same time, although exact standards were not clearly documented in the early 1950's (7, 8, 9).

Long-term performance of the wood preservation product depended on the use of heavier and more persistent components. However, penetration of these constituents, which relies on the lighter, more mobile components, was also important. Petroleum oils (aliphatic compounds) were commonly used as diluents for creosote mixtures, mainly for the purposes of aiding in the penetration of toxic aromatic compounds found in the coal-tar into the wood and for reducing the overall cost of the wood treating. Due to the high viscosity of coal-tar, middle range distillates were routinely used as a vehicle to allow deep penetration of the preservative constituents. Often higher temperatures were also used to aid in penetration of the highly viscous coal-tar material (10).

The US EPA has been involved with the clean-up of abandoned wood treatment sites throughout the United States. The wastes found on these sites vary in physical and chemical characteristics. However, in a guidance document detailing recommended approaches for remediation of uncontrolled wood preserving sites, the US EPA has clearly defined the composition of a creosote or similar wood treating mixture as consisting of: "35% by weight aliphatic hydrocarbon (oil) and 65% by weight polynuclear aromatic" (3).

Laboratory analysis of the aliphatic (oil fraction) and aromatic (tar) fractions of samples from wells MW-15, EW-1 and MW-7 are revealing. The percentage of oil fraction in the sample from well MW-7 is nearly 30%, while the tar fraction from the same sample is nearly 70%. The composition of the sample from MW-7 is consistent with the US EPA definition of a wood treating mixture and represents an intentional mixture of petroleum-derived material. By comparison, only approximately 8% oil fraction and over 92% tar fraction is contained in samples from MW-15 and EW-1. The samples from MW-15 and EW-1 are again highly similar in the results of this analysis.

Based on the results of analyses performed and in comparison with reference standards, IGT concludes that the NAPL material from well MW-7 is distinctly dissimilar from material retrieved from wells MW-15 and EW-1, and that the NAPL material from well MW-7 is consistent with wood treatment activities reportedly conducted at Kreher Park.

REFERENCES

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- 3) *Remedial Action Options Feasibility Study – Final Report – for the Ashland Lakefront Site* (Dames & Moore, March, 1999)
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APPENDIX A

IGT EXPERIENCE

IGT EXPERIENCE

The Institute of Gas Technology (IGT) is an independent, not-for-profit energy and environmental research development and education organization, initially established with the support of the natural gas utility industry in 1941. IGT's role was broadened in the 1970s to encompass the development of environmental management/site remediation technologies. Today, IGT conducts research in all major areas of energy production and utilization, including pollution abatement, environmentally responsible waste management and processing, waste conversion, fossil fuels and renewable resources to clean fuels and chemicals, energy systems analysis, fuel cell technology, hazardous waste cleanup, natural gas distribution and operations, natural gas production and processing, and space conditioning. The Institute's over 250 degreed scientists and engineers are in the forefront of developments in acoustics, catalysis, electrochemistry, energy and environmental biotechnology, environmental engineering, fluidization, and waste detoxification and destruction.

IGT performs contract research for about 75 organizations annually, including Federal and local government agencies, the Gas Research Institute, the Electric Power Research Institute, gas and electric utilities, engineering firms and private industry. The IGT headquarters and laboratories are located in Des Plaines, Illinois. The facilities consist of a 269,000 square-foot building situated on 9 acres. Of the total floor space, some 130,000 square feet on two floors is laboratory space devoted to electrochemistry, biotechnology gas distribution, chemical analysis and chemical process research. The IGT facility possesses a library containing one of the world's largest collections of information on natural gas technology, including more than 33,000 texts and bound journals, over 500 periodical and newsletter subscriptions, 100,000 technical reports, 5,000 patents, 1,000 theses and 130,000 microfiche documents.

IGT has been developing innovative technologies for environmental application since 1965. Through the years, it has established itself as a reputable leader with wide name recognition in the environmental field. IGT has a broad range of experienced technical staff expert in varying areas directly applicable to site management, from environmental assessment to technology development and full-scale remediation. IGT has conducted work on a wide range of sites, but specializes in MGP site management and remediation. IGT has developed and demonstrated treatment processes for the remediation of soil and groundwater contaminated with compounds such as heavy metals, polynuclear aromatic hydrocarbons (PAHs), volatile hydrocarbons (BTEX), polychlorinated biphenyls (PCBs), and cyanide. The laboratories at IGT also possess experience in developing integrated environmental remediation technologies, including unique approaches to combined biological, chemical, and physical approaches. IGT has three technologies in the U.S. EPA's SITE program and has recently completed field testing of two environmental remediation technologies for the treatment of soil containing organic pollutants.

IGT is known for its ability to integrate business and technical evaluations to construct site management programs which both meet client and regulatory requirements. Serving as a key player in regulatory negotiations, IGT has been able to provide technical and supporting evidence for reasonable site closures. IGT routinely interfaces with regulators in many states each year and holds work shops for them on innovative and effective site closure approaches.

IGT is viewed by many regulators as an impartial third party. This reputation, scientific credibility and the ability to articulate complicated technical issues to regulators and other shareholders has led to acceptance of IGT's site management programs. Consequently, IGT has been able to secure less aggressive site management programs for its members and clients at lower overall costs, while continuing to meet the needs of the regulators. Providing assistance in rate recovery and insurance issues has also been a key focus at IGT. Overall, IGT has established credibility as an impartial evaluator of site management strategies, ranging from site monitoring only to full-scale remediation.

IGT is also able to provide community relations services, select appropriate and prudent remedial options for site closure, define milestones for site monitoring programs, prepare work plans for remediation and assist in contractor selection, implement and track remedial progress and share in the risk and benefits with member companies for cost effective site management.

APPENDIX B

LABORATORY DATA

November 16, 1999

Dr. Diane Saber
Institute of Gas Technology
1700 S. Mt. Prospect Road
Des Plaines, IL 60018

RE: Environmental Forensic Analysis of Two NAPL Samples

Dear Dr. Saber:

META Environmental, Inc. (META) has completed the analysis of two NAPL samples for monocyclic aromatic hydrocarbons (MAHs), polycyclic aromatic hydrocarbons (PAHs), and hydrocarbon fingerprint by gas chromatography with flame ionization detection (GC/FID). The concentrations of MAHs and PAHs and the GC/FID fingerprints are provided at the end of this letter report.

Methods

Two sample preparation methods were needed. First, 0.0110 g of the NAPL layer of Sample MW-15 was quantitatively diluted in methylene chloride. Next, because there was not sufficient NAPL in Sample MW-7 to collect it separately, 18.396 mL of NAPL/water mixture were microextracted with 2.0 mL of methylene chloride. The extract was split and 0.50 mL were evaporated to dryness; the weight of residue from this procedure was used to estimate the weight of NAPL in the extract. The other portion of the MW-7 extract was used for GC/FID analysis. Finally, prior to instrumental analysis, internal standards, 2,4-difluorotoluene and o-terphenyl were added to each extract.

Results

The GC/FID fingerprints reveal two different types of tar. Sample MW-15 exhibits the characteristics of many former MGP tars, including very high relative amounts of parent PAHs, high relative naphthalene concentration, low relative amounts of dibenzofuran, a fluoranthene/pyrene ratio less than 1, no apparent unresolved complex mixture (UCM), and no visible alkane pattern or isoprenoid hydrocarbons.

In contrast, Sample MW-7 appears to be a mixture of former MGP tar and a middle petroleum distillate, as indicated by the distinct UCM eluting from about 10 minutes to about

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Prepared in Anticipation of Litigation

35 minutes with numerous individual peaks in that retention time range. The petroleum distillate content interferes with the tar pattern and potentially the concentrations of compounds such as acenaphthylene, dibenzofuran, and fluorene. It is impossible to determine from the available data whether the material in MW-7 was a plant byproduct, whether the mixture was intentionally produced by mixing tar and middle distillate, or whether the mixture was unintentionally produced as can occur when petroleum products and tars mix in the subsurface or in ponds.

The GC/FID fingerprints of several reference materials have been included in this report. They include a commercial creosote, a mixture of seven former MGP tars (EPRI, 1993), a tar from a carburetted water gas (CWG) plant, a gas oil sample, and a diesel fuel sample. The commercial creosote was produced from high temperature coal tar as per American Wood Preservers Association specifications. It has many of the same features as lower temperature coal tars and CWG tars, however, the high fluoranthene/pyrene ratio and the relatively high concentrations of dibenzofuran are indicators of high temperature coal tar origin. The EPRI tar mixture exhibits PAH ratios and characteristics that are between those of the CWG tar and the creosote. This occurs because the EPRI tar mixture contains equal amounts of tars from seven former MGP sites that had a variety of types of MGPs.

While Samples MW-7 and MW-15 are distinctly different from each other, they also do not match the patterns in the commercial creosote or the EPRI tar mixture. The GC/FID fingerprint of Sample MW-15 is very similar to that of the CWG tar.

If you have any questions regarding these results, or would like to request additional analyses, please call me.

Sincerely,



David M. Mauro
V. President

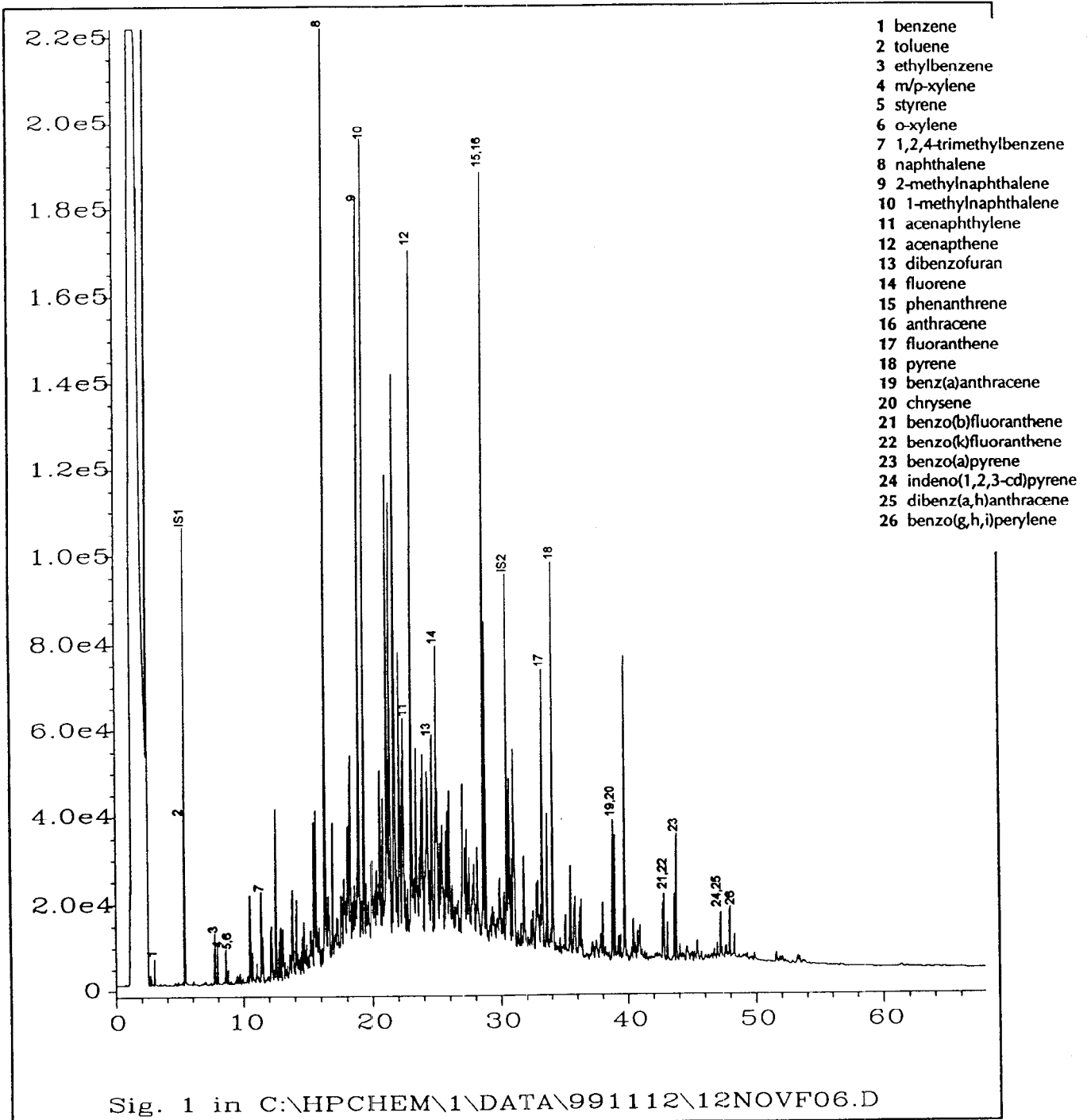
attachment

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Prepared in Anticipation of Litigation

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene

IS2 - o-terphenyl

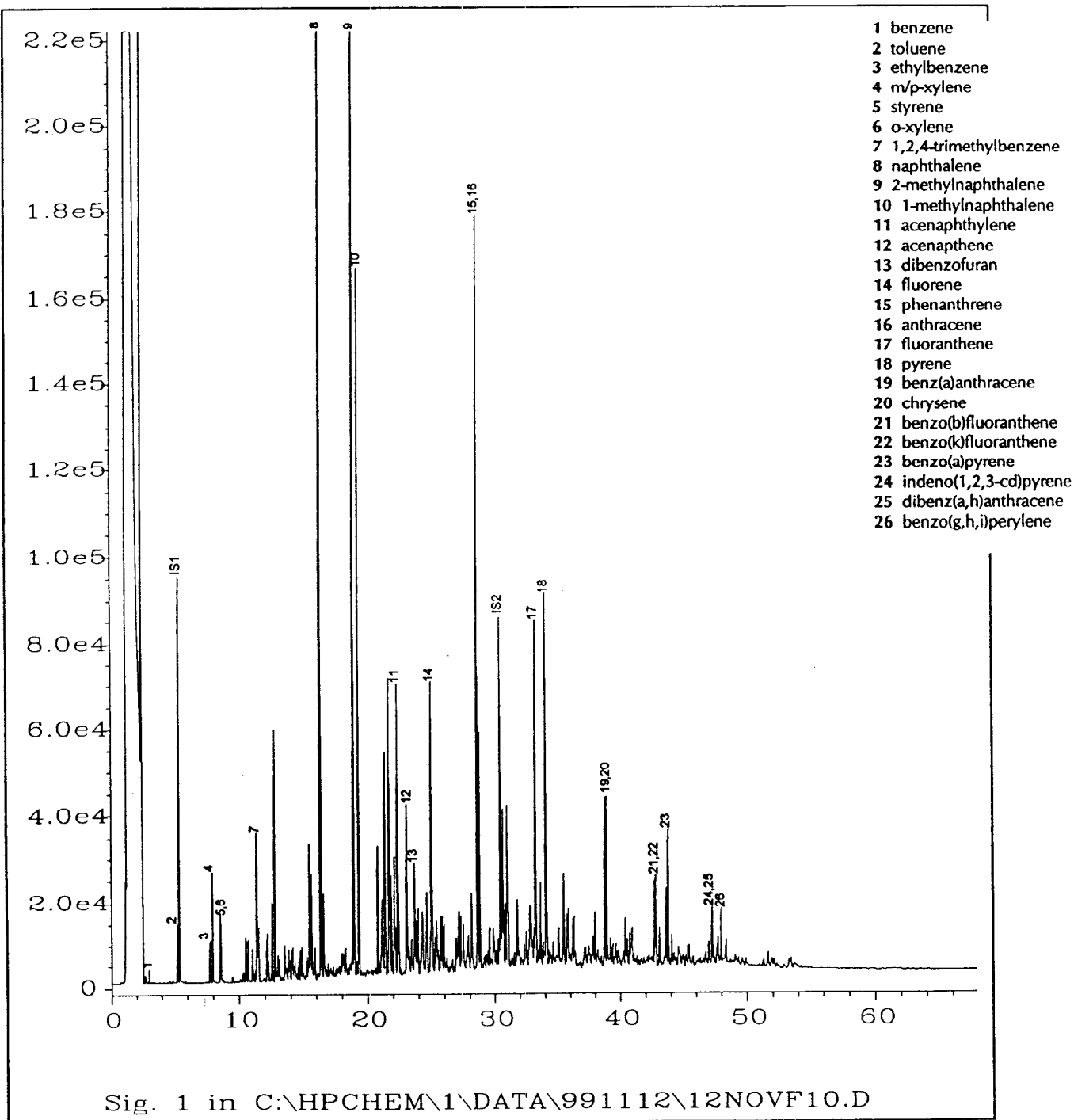
S1 - fluorobenzene

S2 - 2-fluorobiphenyl

S3 - 5a-androstane

Field ID: **MW-7**
Laboratory ID: **IG991110-01**
Method: **MET4007D**

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene

IS2 - o-terphenyl

S1 - fluorobenzene

S2 - 2-fluorobiphenyl

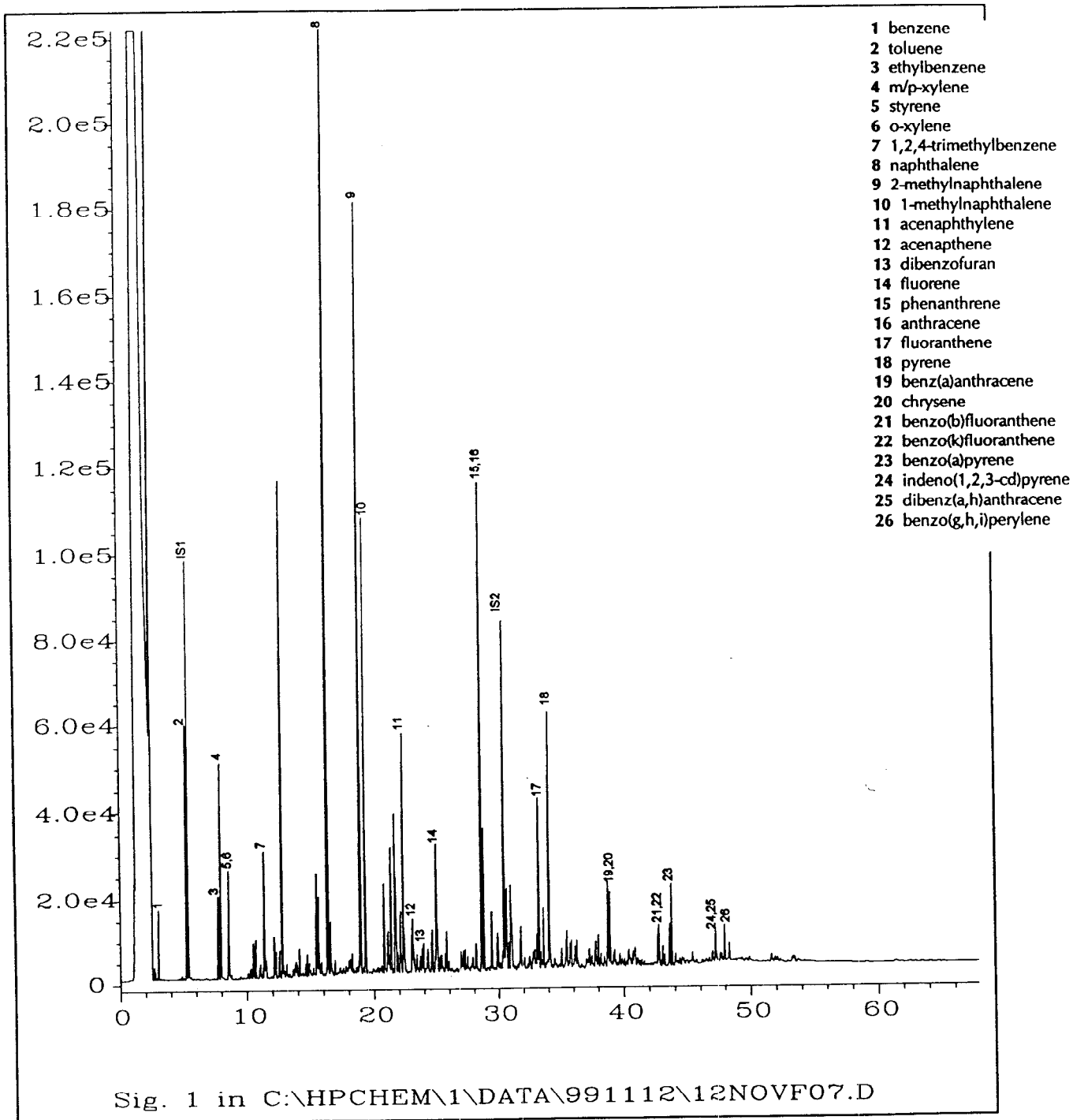
S3 - 5a-androstane

Field ID: **EPRI Mix 911022 (T012)**

Laboratory ID: **EL991110-03**

Method: **MET4007D**

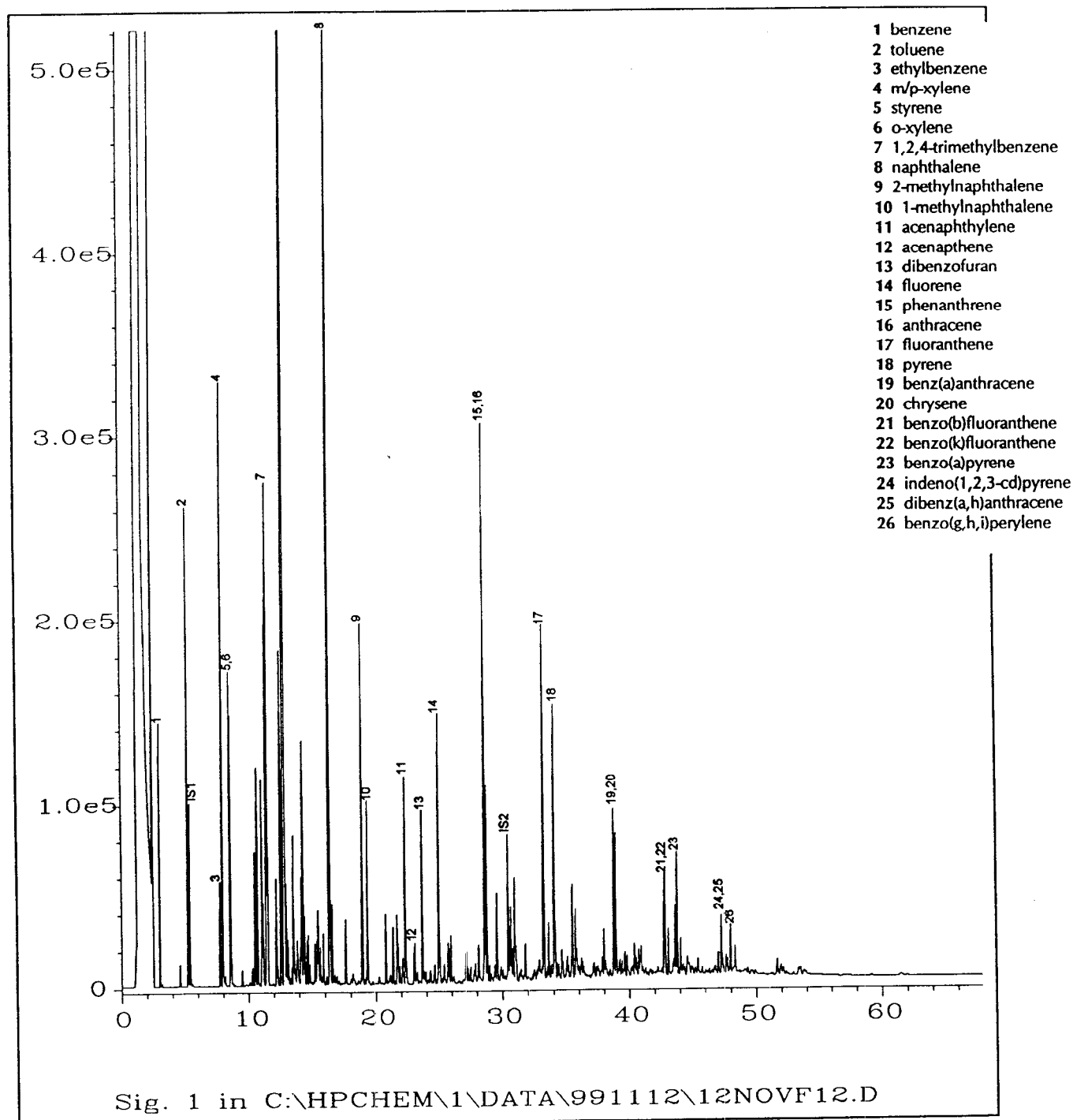
GC/FID Fingerprint



IS1 - 2,4-difluorotoluene
 IS2 - o-terphenyl
 S1 - fluorobenzene
 S2 - 2-fluorobiphenyl
 S3 - 5a-androstane

Field ID: **MW-15**
 Laboratory ID: **IG991110-02**
 Method: **MET4007D**

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene

IS2 - o-terphenyl

SI - fluorobenzene

S2 - 2-fluorobiphenyl

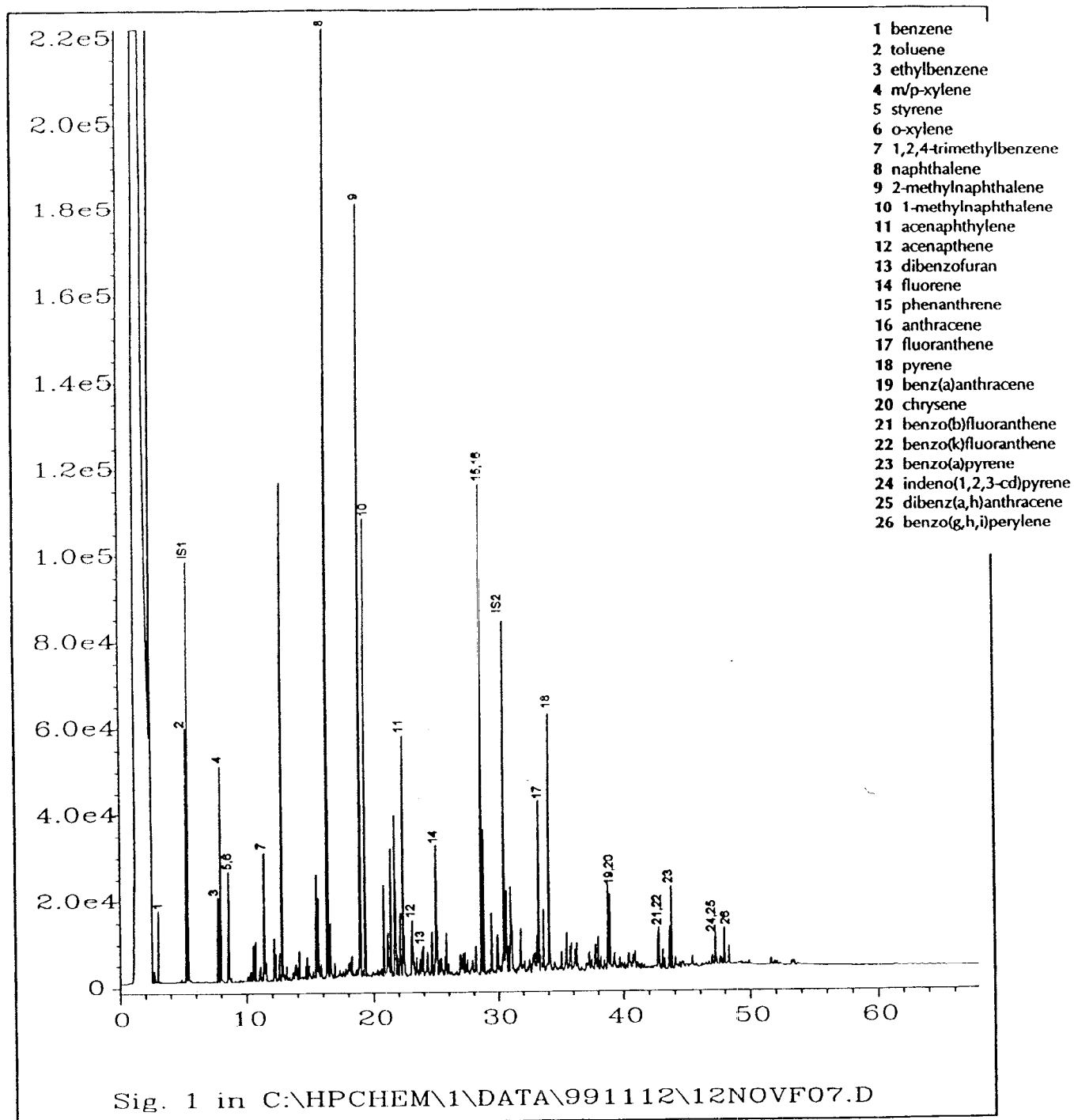
S3 - 5 α -androstane

Field ID: **Cresote (T124)**

Laboratory ID: EL991110-05

Method: MET4007D

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene

IS2 - o-terphenyl

S1 - fluorobenzene

S2 - 2-fluorobiphenyl

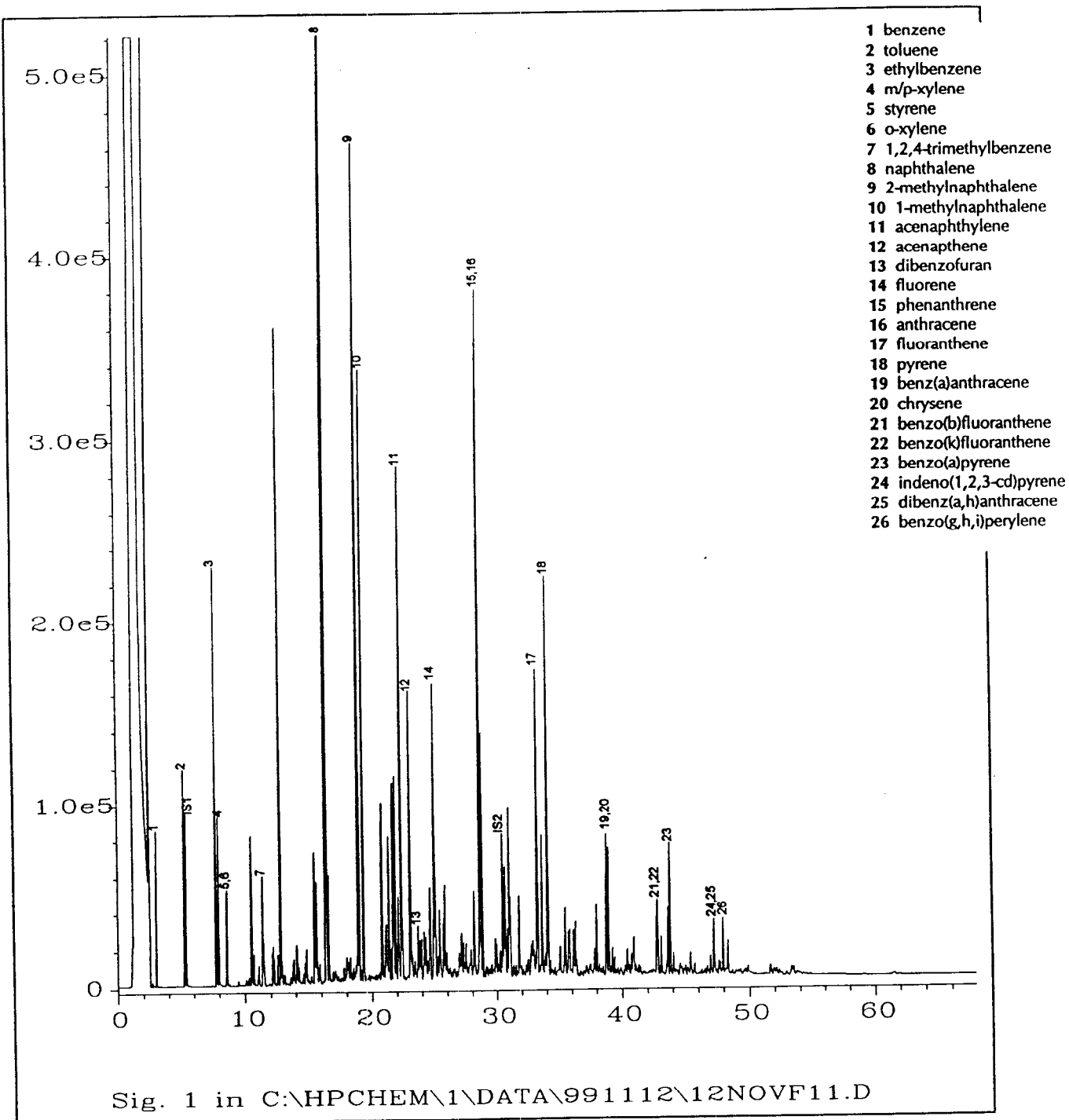
S3 - 5a-androstane

Field ID: **MW-15**

Laboratory ID: IG991110-02

Method: MET4007D

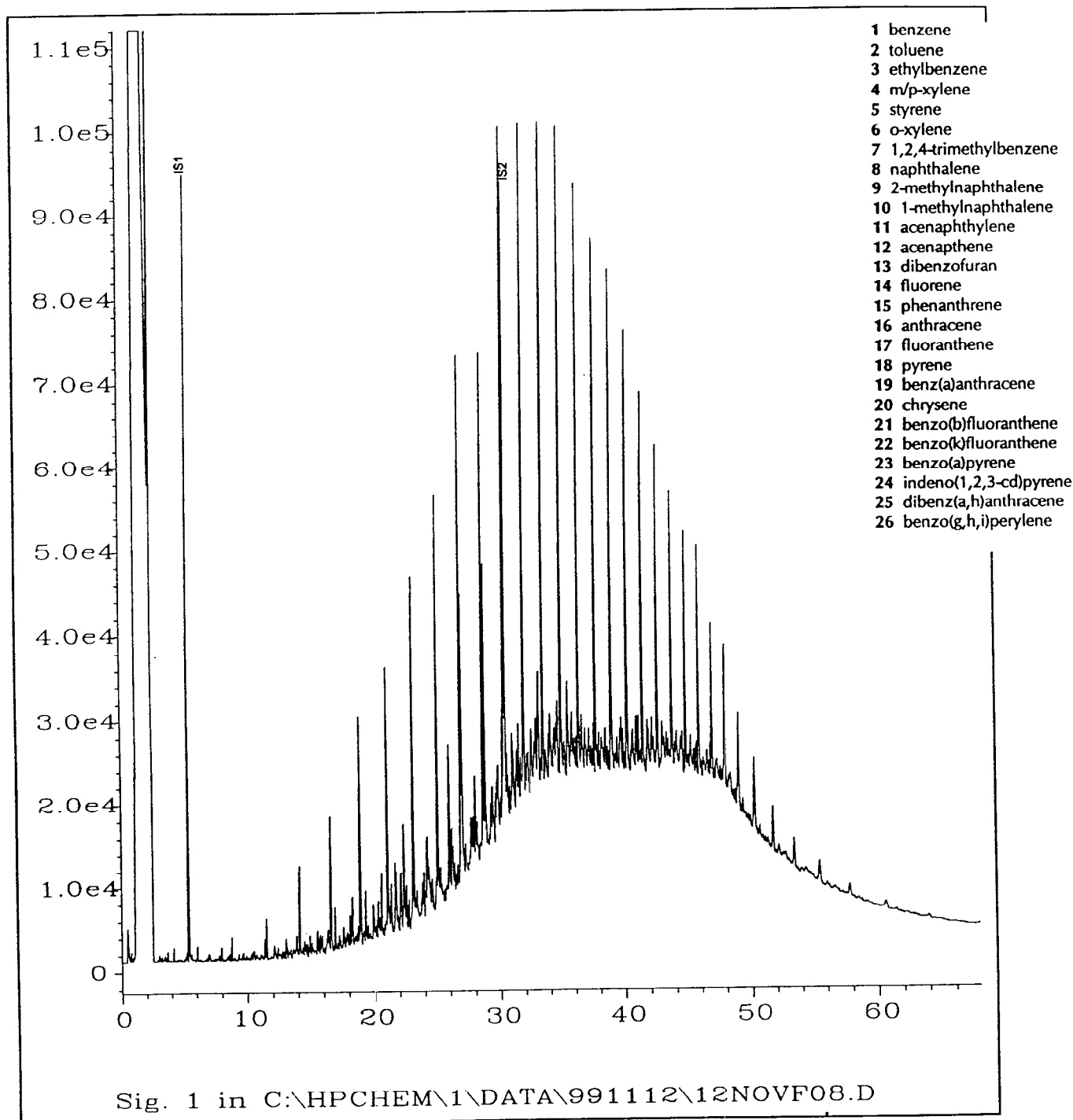
GC/FID Fingerprint



IS1 - 2,4-difluorotoluene
IS2 - o-terphenyl
S1 - fluorobenzene
S2 - 2-fluorobiphenyl
S3 - 5 α -androstane

Field ID: **CWG Tar (T168)**
Laboratory ID: **EL991110-04**
Method: **MET4007D**

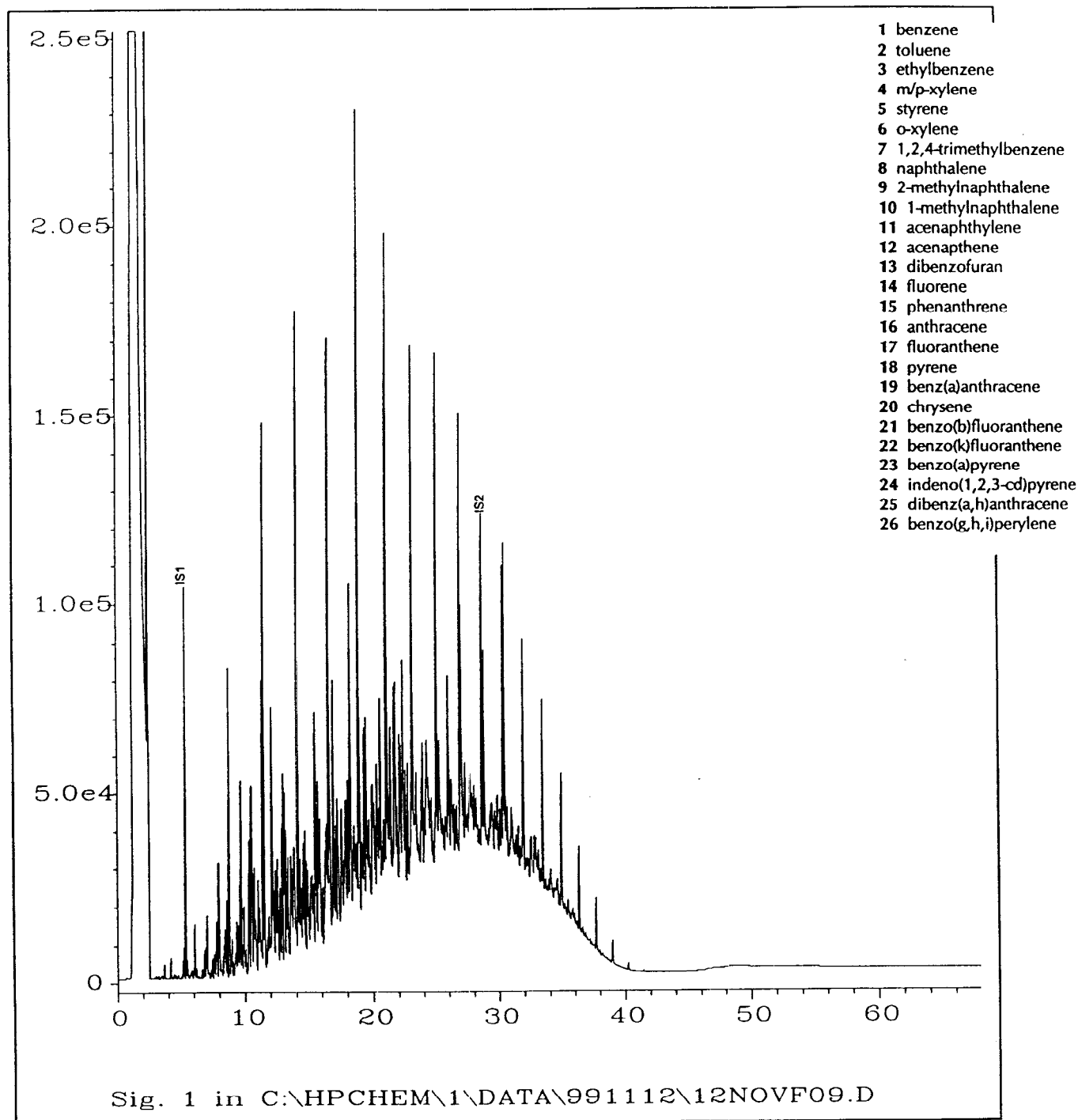
GC/FID Fingerprint



IS1 - 2,4-difluorotoluene
IS2 - o-terphenyl
S1 - fluorobenzene
S2 - 2-fluorobiphenyl
S3 - 5 α -androstane

Field ID: **High Sulfur Gas Oil Feed**
Laboratory ID: EL991110-01
Method: MET4007D

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene

IS2 - o-terphenyl

S1 - fluorobenzene

S2 - 2-fluorobiphenyl

S3 - 5a-androstane

Field ID: **Diesel**

Laboratory ID: EL991110-02

Method: MET4007D

META ENVIRONMENTAL SAMPLE RECEIPT

Lab ID	Field ID	Matrix	Analysis	Date Sampled	Date Received	Client/Project	Container/Storage	Comments/Logger
IG991110-01	MW-7	NAPL	2512/4007	11/09/99	11/10/99	I05001-60	4x40mL VOA	
IG991110-02	MW-15	NAPL	2512/4007	11/09/99	11/10/99	I05001-60	4x40mL VOA, 8 oz amber	

Michael B. Smith
11/10/99

December 2, 1999

Dr. Diane Saber
Institute of Gas Technology
1700 S. Mt. Prospect Road
Des Plaines, IL 60018

RE: DRAFT REPORT
Environmental Forensic Analysis of NAPL Sample, EW-1

Dear Dr. Saber:

META Environmental, Inc. (META) has completed the analysis of one NAPL sample for monocyclic aromatic hydrocarbons (MAHs), polycyclic aromatic hydrocarbons (PAHs), and hydrocarbon fingerprint by gas chromatography with flame ionization detection (GC/FID). This draft report presents and discusses the GC/FID fingerprint results.

Method

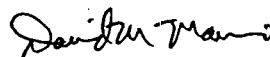
A portion of Sample EW-1 was quantitatively diluted in methylene chloride. Then, prior to instrumental analysis, internal standards, 2,4-difluorotoluene and o-terphenyl were added to the extract.

Results

The sample is a tar based on GC/FID fingerprint matching. There are no indications of any other substance present in the sample. Also, the GC/FID fingerprint of sample EW-1 was very similar to that of sample MW-15, received from you on November 10.

The additional analyses that you requested will be finished shortly.

Sincerely,



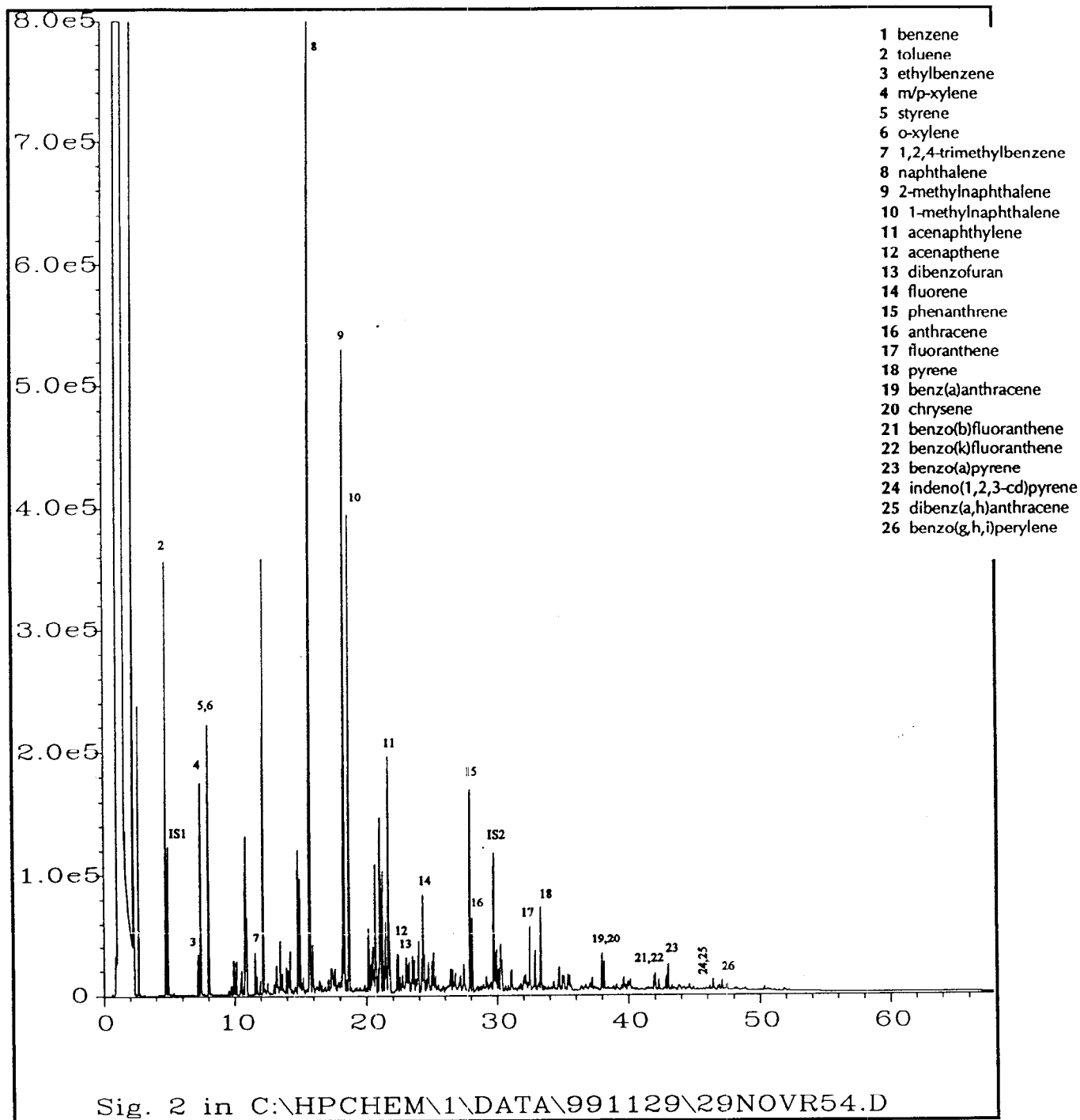
David M. Mauro
V. President

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Prepared Under the Direction of Counsel

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Prepared in Anticipation of Litigation

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene
 IS2 - o-terphenyl
 SS1 - fluorobenzene
 SS2 - 2-fluorobiphenyl
 SS3 - 5- α -androsterone

Field ID: **EW-1**
 Laboratory ID: **IG991123-01**
 Method: **MET4007**

December 14, 1999

Dr. Diane Saber
Institute of Gas Technology
1700 S. Mt. Prospect Road
Des Plaines, IL 60018

RE: Report: Environmental Forensic Analysis of 3 NAPL Samples

Dear Dr. Saber:

META Environmental, Inc. (META) has completed the analysis of three non-aqueous phase liquid (NAPL) samples, MW-7, MW-15, and EW-1, for environmental forensic parameters. Those parameters included, monocyclic aromatic hydrocarbons (MAHs), polycyclic aromatic hydrocarbons (PAHs), hydrocarbon fingerprint by gas chromatography with flame ionization detection (GC/FID), aliphatic hydrocarbons, and polar hydrocarbons.

The results for MAHs, PAHs, and hydrocarbon fingerprint have been provided to you in reports dated November 16, 1999 (MW-7 and MW-15) and December 2, 1999 (EW-1). This report provides the results of analyses for the aliphatic, aromatic, and polar hydrocarbon fractions of the three NAPLs.

Method

Portions of Samples MW-15 and EW-1 were quantitatively diluted in methylene chloride. Because Sample MW-7 was a NAPL/water mixture, it was microextracted into methylene chloride. The methylene chloride extracts were analyzed directly by GC/FID for MAHs, PAHs, and hydrocarbon fingerprint.

A second portion of each methylene chloride extract was spiked with surrogate compounds (2,5-dibromotoluene, 2-bromonaphthalene, and 1-chlorooctadecane) and then fractionated into aliphatic, aromatic, and polar fractions using silica gel column chromatography according to EPA Method 3611. Each fraction was concentrated to a known final volume, spiked with internal standards, and analyzed by GC/FID.

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The following is an example of the sample identification codes for the fractions:

IG991110-02UF	whole extract
IG991110-02PF	aliphatic fraction (in pentane)
IG991110-02DF	aromatic fraction (in methylene chloride, DCM)
IG991110-02MF	polar fraction (in methanol)

Results

The GC/FID fingerprints for the aliphatic and polar fractions are included in this report. Also, the GC/FID fingerprints of the whole extracts and the aromatic fractions are provided.

As reported previously, the GC/FID fingerprints of the whole extracts of samples MW-15 and EW-1 are very similar (although not exact). As expected, the GC/FID fingerprints of the aromatic fractions were also very similar. Also, the GC/FID fingerprints of the aliphatic fractions were very similar, resembling a middle weight petroleum distillate. Finally, neither polar fraction contained detectable levels of tar acids (phenol and alkylated phenols). Based on these data, samples MW-15 and EW-1 are carburetted water gas tars, and are likely from the same source.

The GC/FID fingerprints of all fractions of sample MW-7 were different from those of samples MW-15 and EW-1. For example, the aliphatic fraction of sample MW-7 shows a weathered middle petroleum distillate with a boiling point range similar to that observed in the aliphatic fractions of samples MW-15 and EW-1. Because sample MW-7 consisted of a NAPL sheen and very small droplets in water, it is possible that biodegradation has acted on the NAPL to completely remove the normal alkanes and that dissolution of some of the lighter compounds has occurred. These same weathering processes would also selectively remove the light aromatic hydrocarbons and the polar compounds, found at much lower relative amounts in MW-7 as compared to the other samples. In contrast, the patterns of weathering-resistant compounds, such as the high molecular weight PAHs, are nearly the same for all three samples.

Finally, the concentrations of total extractable hydrocarbons, total aliphatic hydrocarbons, and total aromatic hydrocarbons were determined, and are reported in Table 1. The compositions of samples MW-15 and EW-1 are very similar, consisting of 5.5 to 11 percent aliphatic and 83 to 88 percent aromatic hydrocarbons. In contrast the composition of sample MW-7 was 28 percent aliphatic hydrocarbons and 65 percent aromatic hydrocarbons. Given the comparatively high proportion of aliphatic hydrocarbons in MW-7 and the advanced stage of weathering of that material, the data suggest that MW-7 NAPL is from a source separate from

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that of MW-15 and EW-1, or that MW-7 represents a mixture of petroleum-derived material and tar.

Table 1 Aliphatic and Aromatic Hydrocarbons in NAPL Samples					
Sample	TEH (mg/kg)	Aliphatic (mg/kg)*	Aromatic (mg/kg)*	% Aliphatic	% Aromatic
MW-7	1,270	350	830	28	65
MW-15	540	46	460	8.5	85
MW-15dup	540	59	450	11	83
EW-1	730	40	640	5.5	88
TEH - total extractable hydrocarbons * concentrations have been corrected for surrogate recoveries					

If you have any questions regarding these data, please call me.

Sincerely,



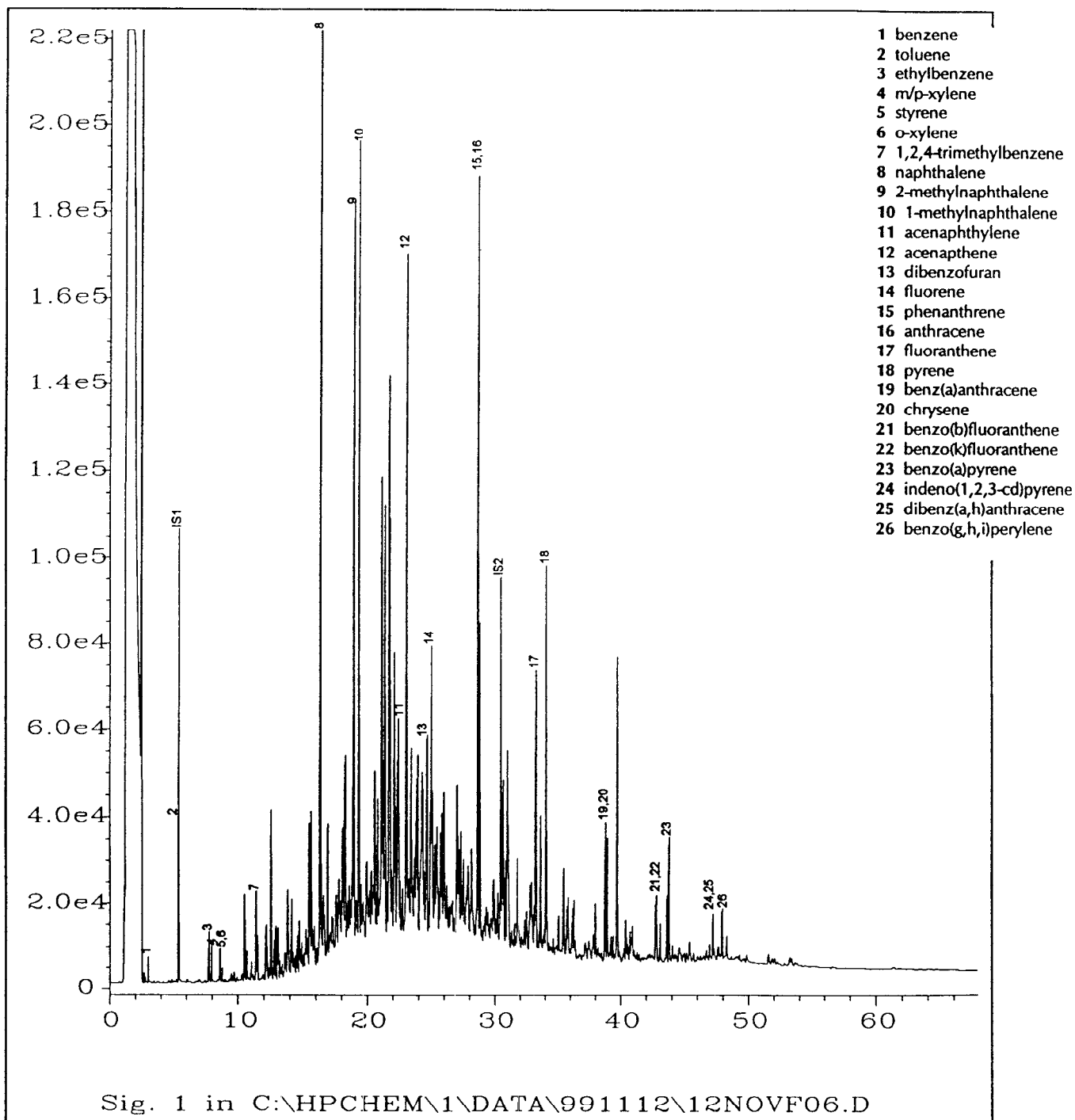
David M. Mauro
V. President

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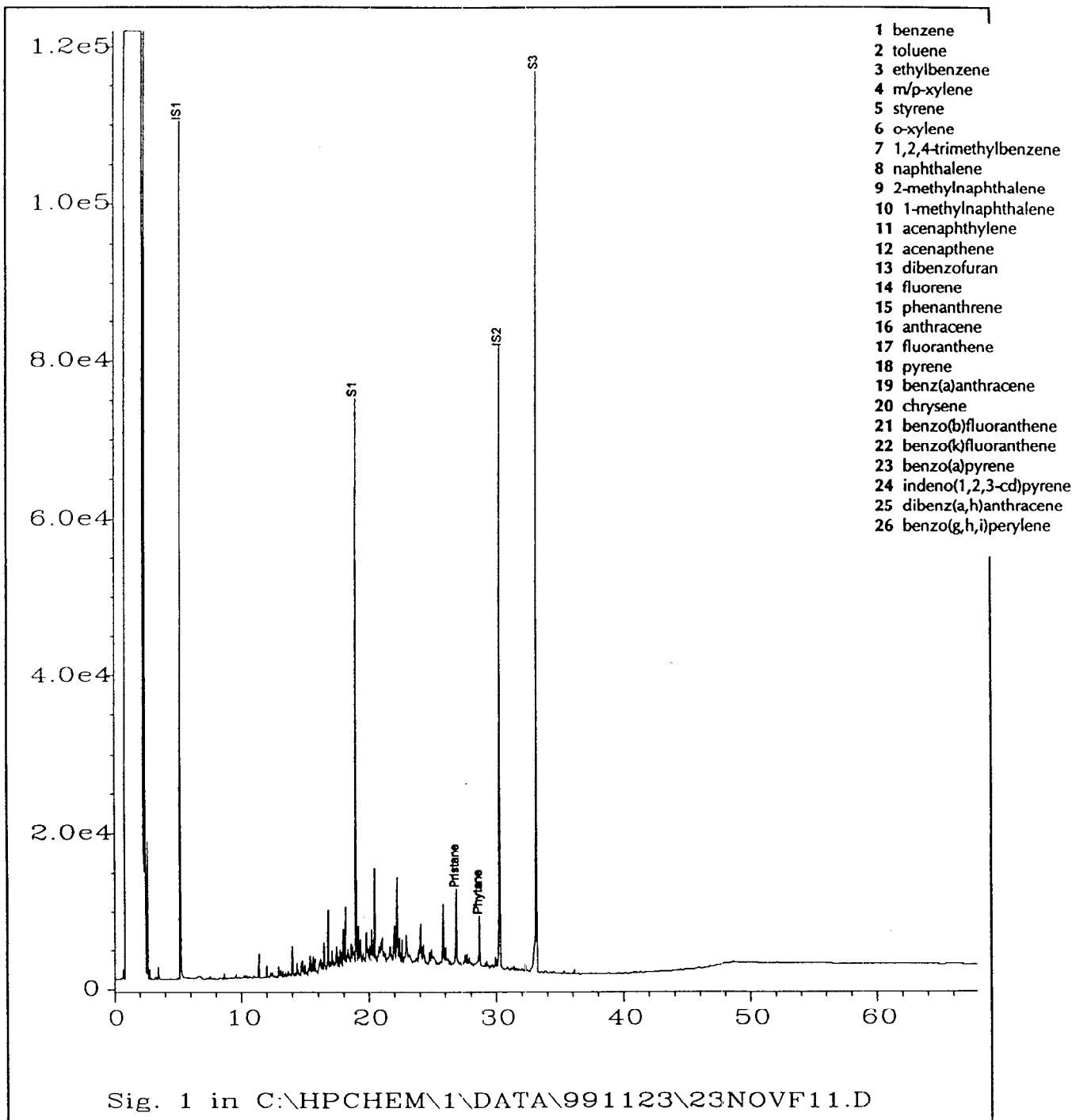
GC/FID Fingerprint



IS1 - 2,4-difluorotoluene
 IS2 - o-terphenyl
 S1 - fluorobenzene
 S2 - 2-fluorobiphenyl
 S3 - 5a-androstane

Field ID: **MW-7**
 Laboratory ID: **IG991110-01**
 Method: **MET4007D**

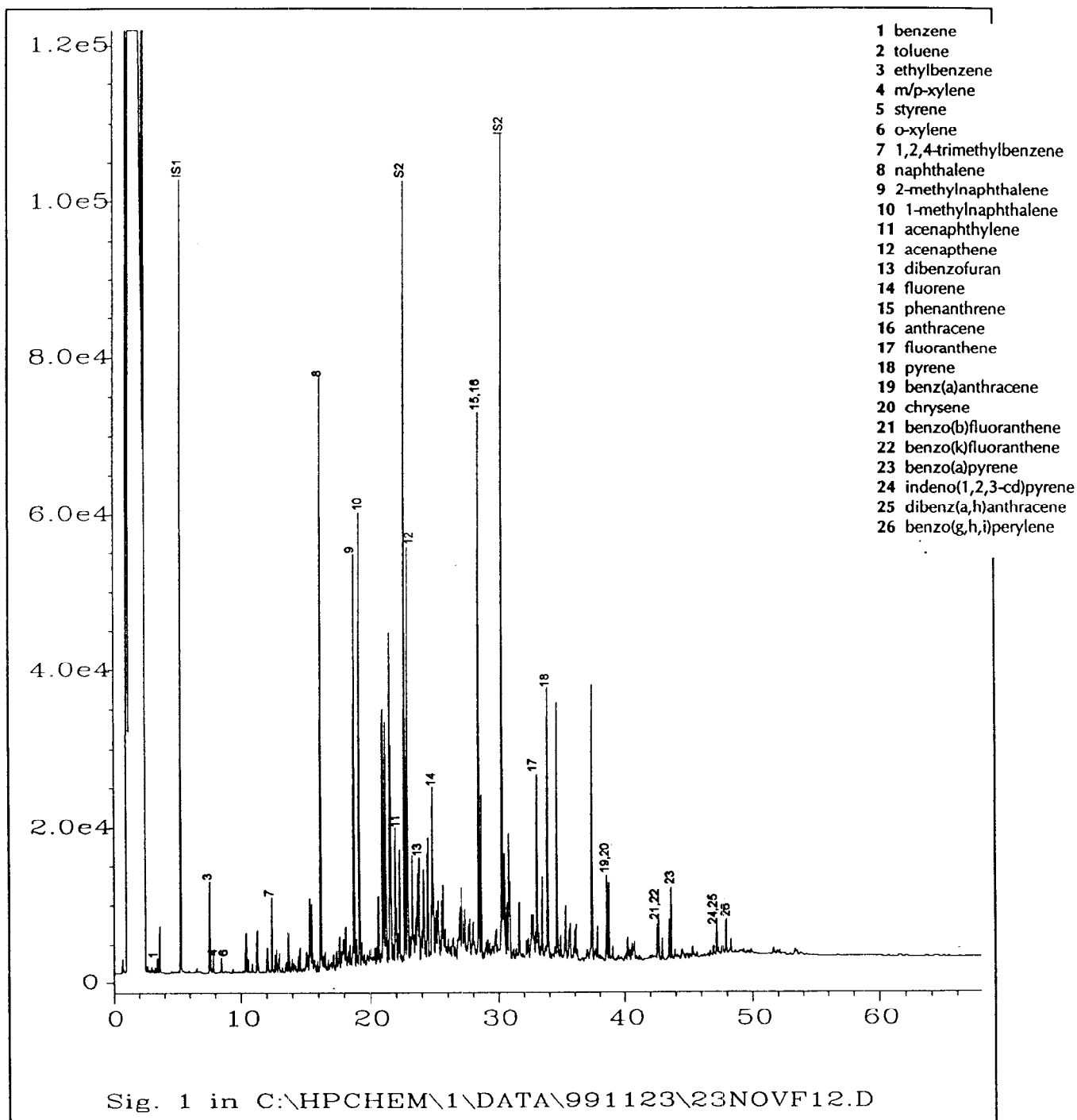
GC/FID Fingerprint



IS1 - 2,4-difluorotoluene
IS2 - o-terphenyl
S1 - 2,5-dibromotoluene
S2 - 2-bromonaphthalene
S3 - 1-chlorooctadecane

Field ID: **MW-7**
Laboratory ID: **IG991110-01PF**
Method: **MET4007D**

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene

IS2 - o-terphenyl

S1 - 2,5-dibromotoluene

S2 - 2-bromonaphthalene

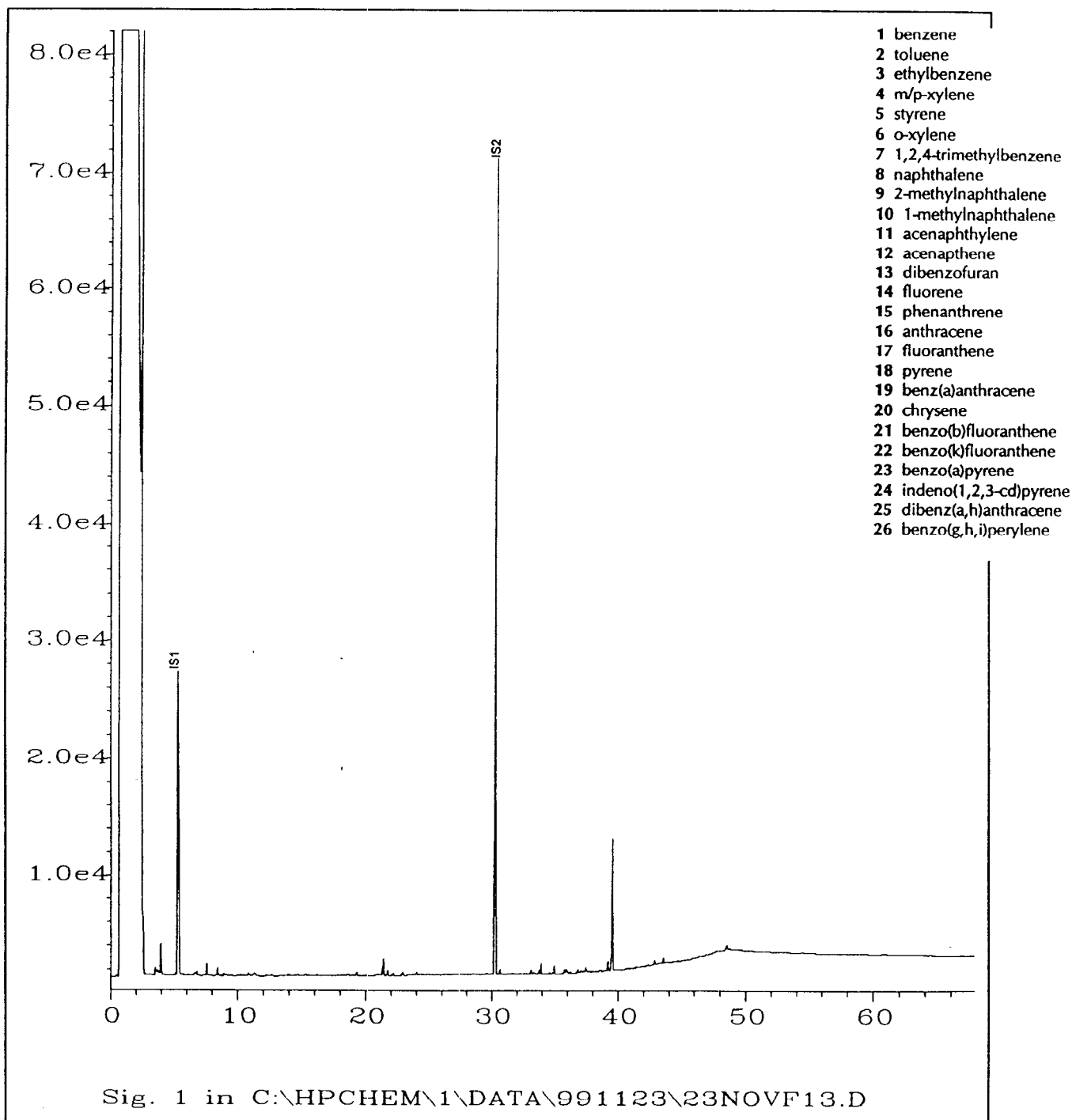
S3 - 1-chlorooctadecane

Field ID: **MW-7**

Laboratory ID: **IG991110-01DF**

Method: **MET4007D**

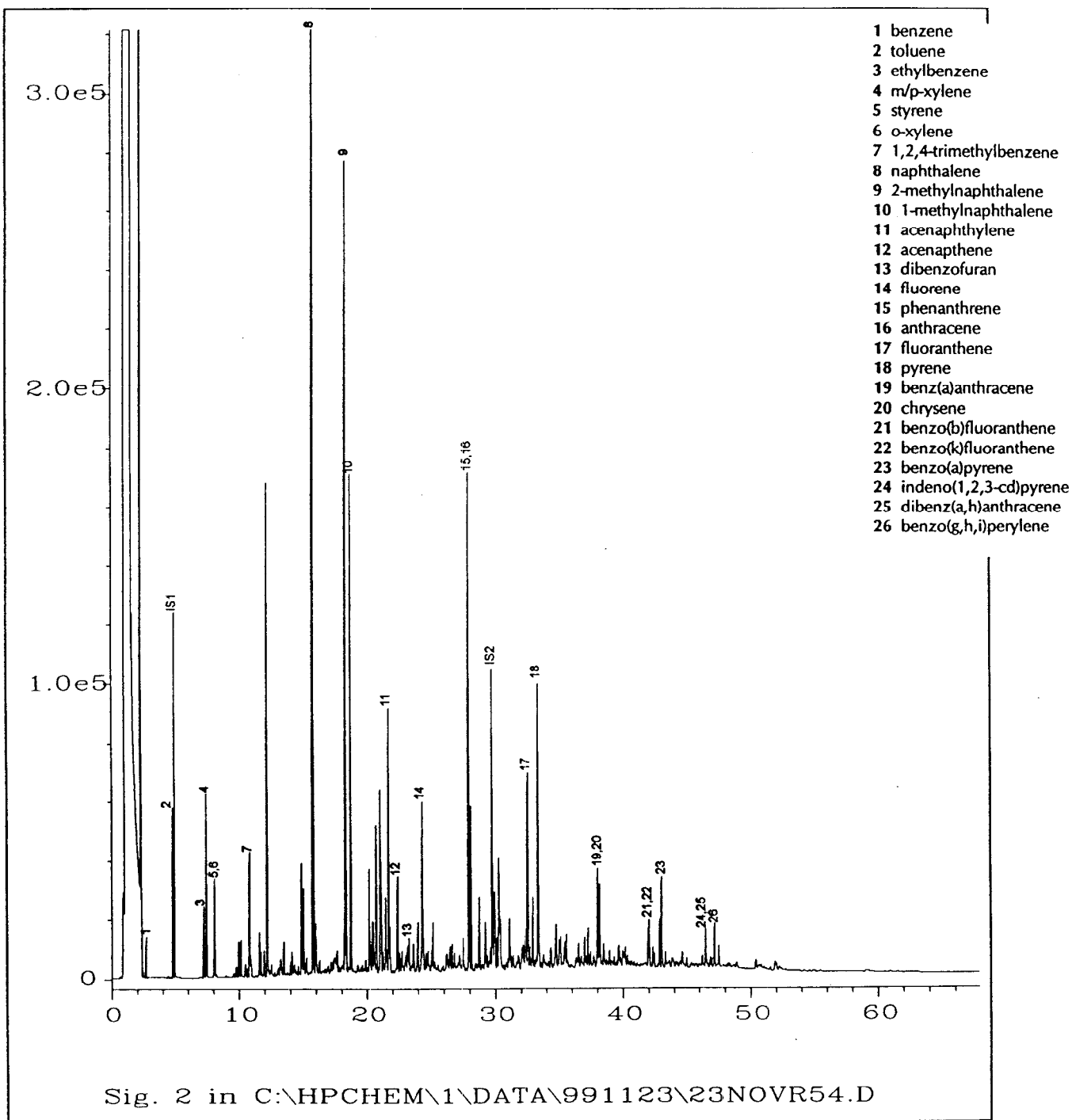
GC/FID Fingerprint



IS1 - 2,4-difluorotoluene
IS2 - o-terphenyl
S1 - 2,5-dibromotoluene
S2 - 2-bromonaphthalene
S3 - 1-chlorooctadecane

Field ID: **MW-7**
Laboratory ID: IG991110-01MF
Method: MET4007D

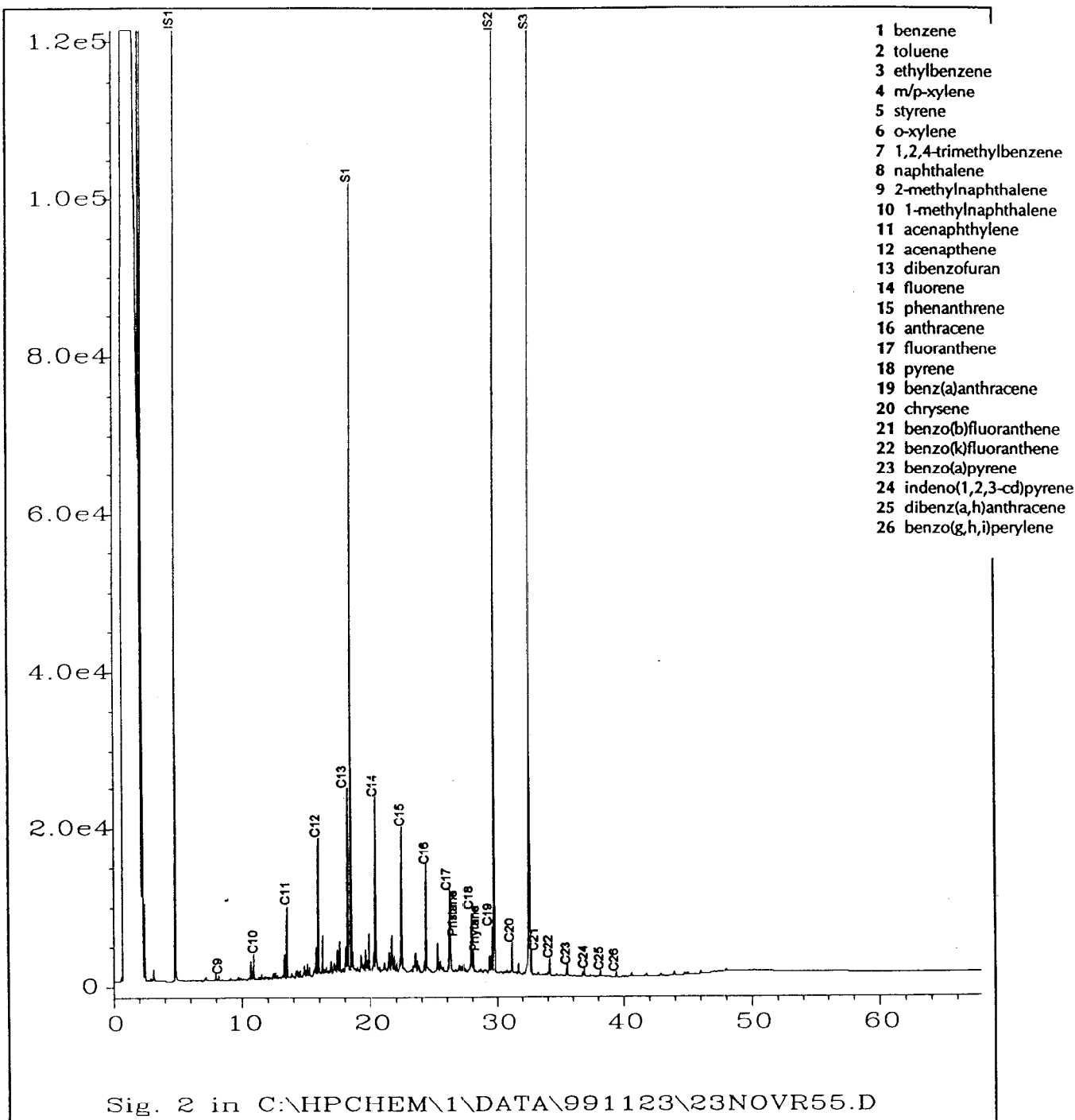
GC/FID Fingerprint



IS1 - 2,4-difluorotoluene
IS2 - o-terphenyl
S1 - fluorobenzene
S2 - 2-fluorobiphenyl
S3 - 5 α -androstande

Field ID: **MW-15**
Laboratory ID: IG991110-02
Method: MET4007D

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene

IS2 - o-terphenyl

S1 - 2,5-dibromotoluene

S2 - 2-bromonaphthalene

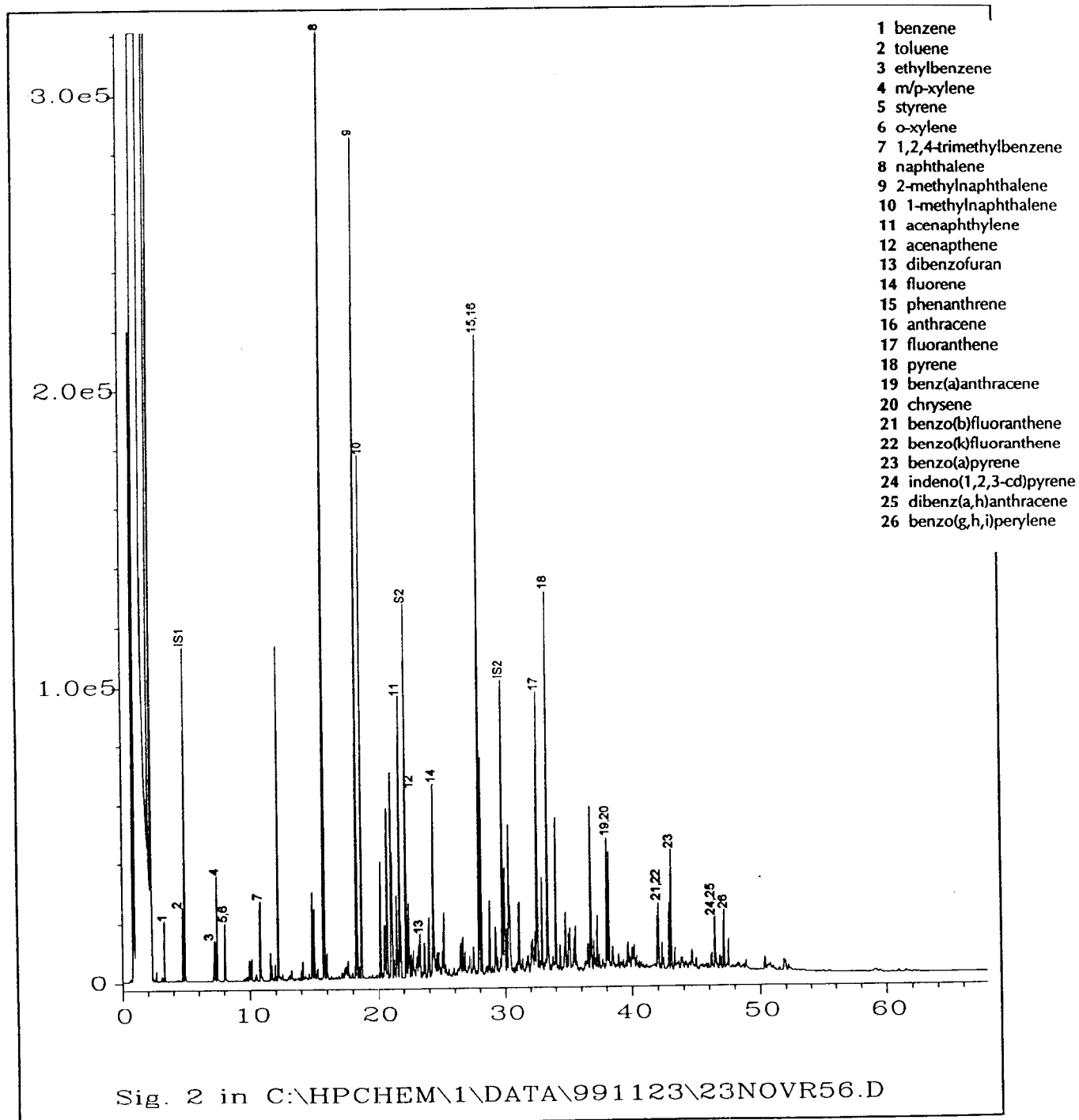
S3 - 1-chlorooctadecane

Field ID: **MW-15**

Laboratory ID: IG991110-02PF

Method: MET4007D

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene

IS2 - o-terphenyl

S1 - 2,5-dibromotoluene

S2 - 2-bromonaphthalene

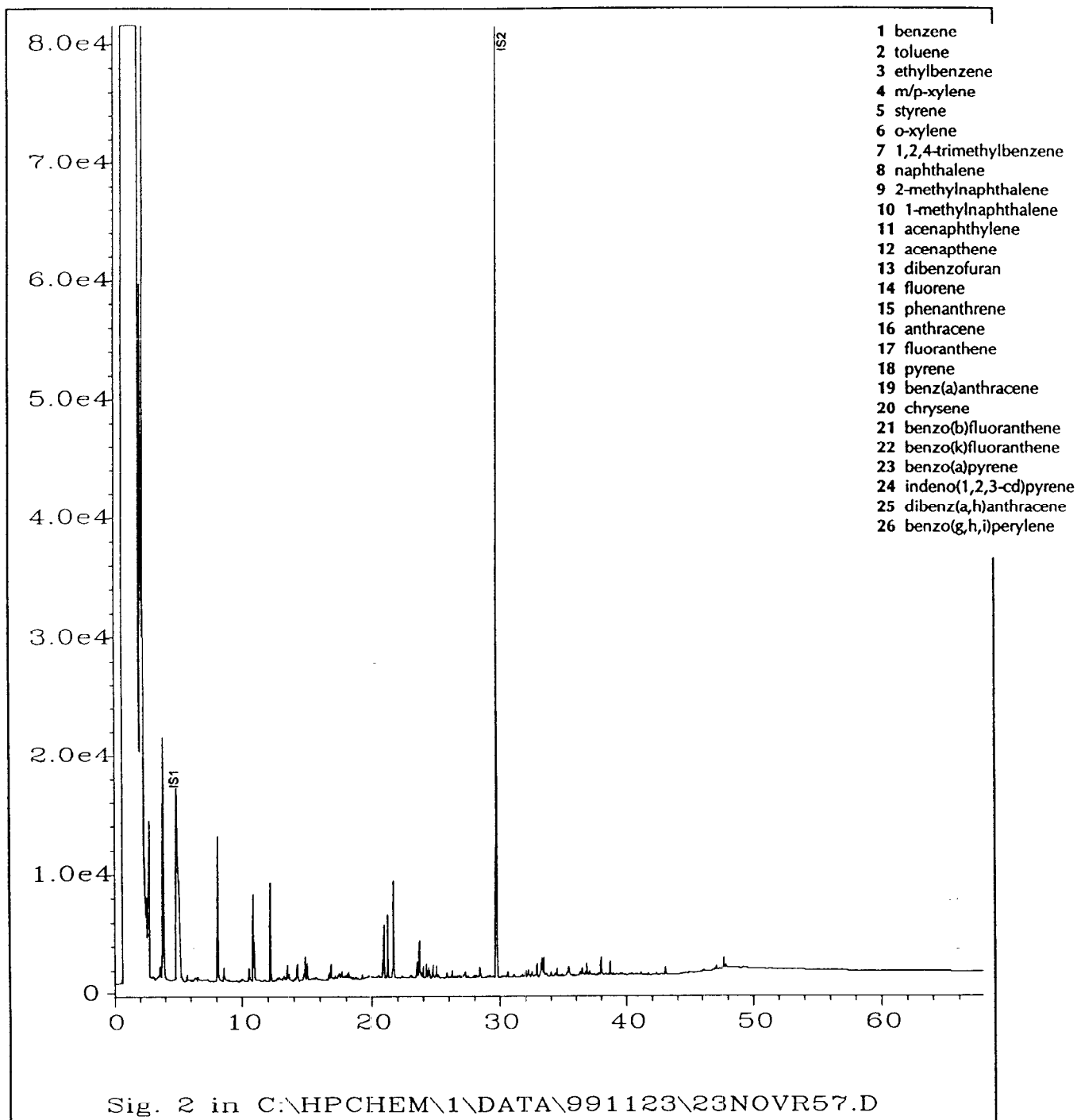
S3 - 1-chlorooctadecane

Field ID: **MW-15**

Laboratory ID: IG991110-02DF

Method: MET4007D

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene

IS2 - o-terphenyl

S1 - 2,5-dibromotoluene

S2 - 2-bromonaphthalene

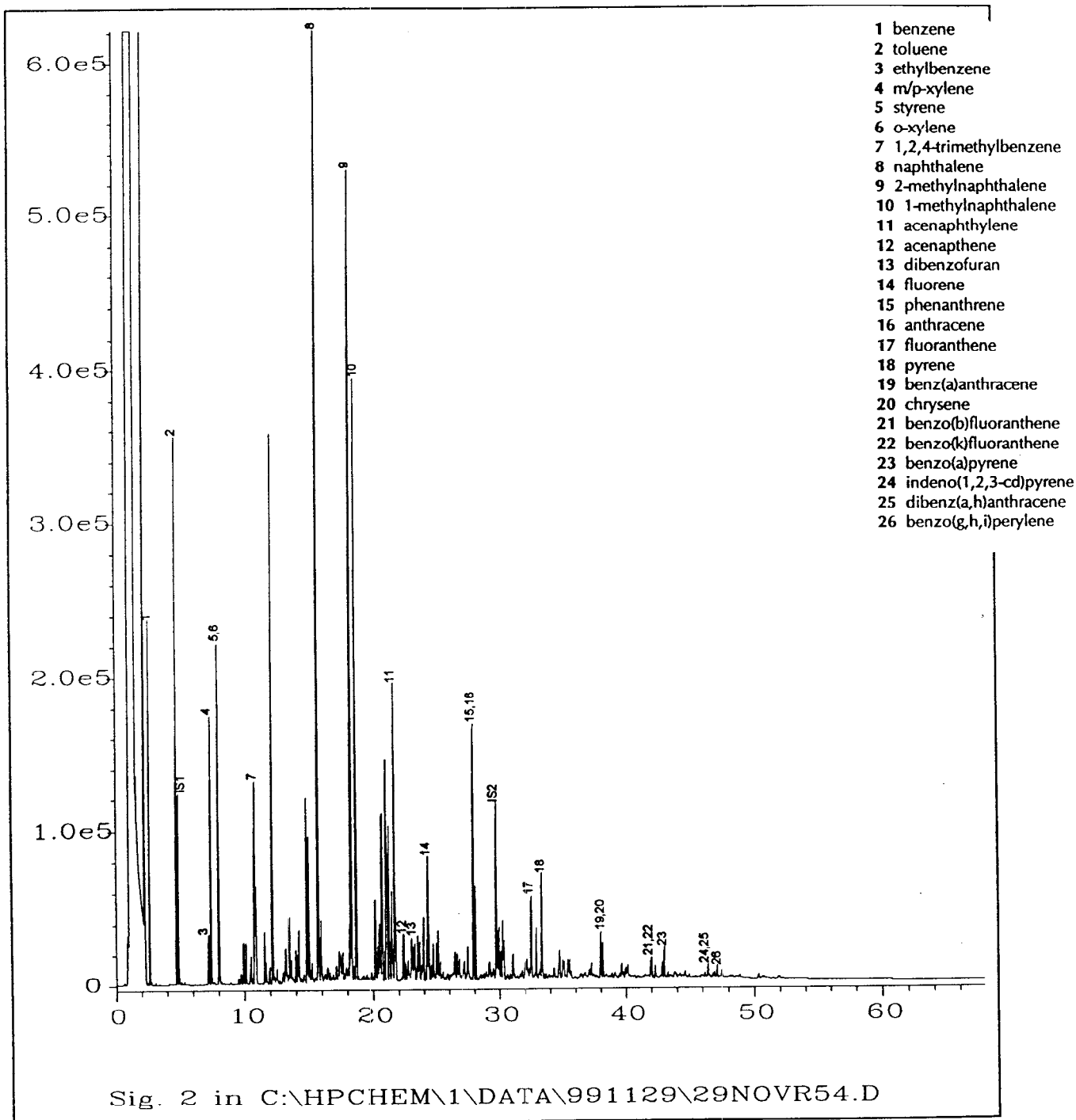
S3 - 1-chlorooctadecane

Field ID: **MW-15**

Laboratory ID: IG991110-02MF

Method: MET4007D

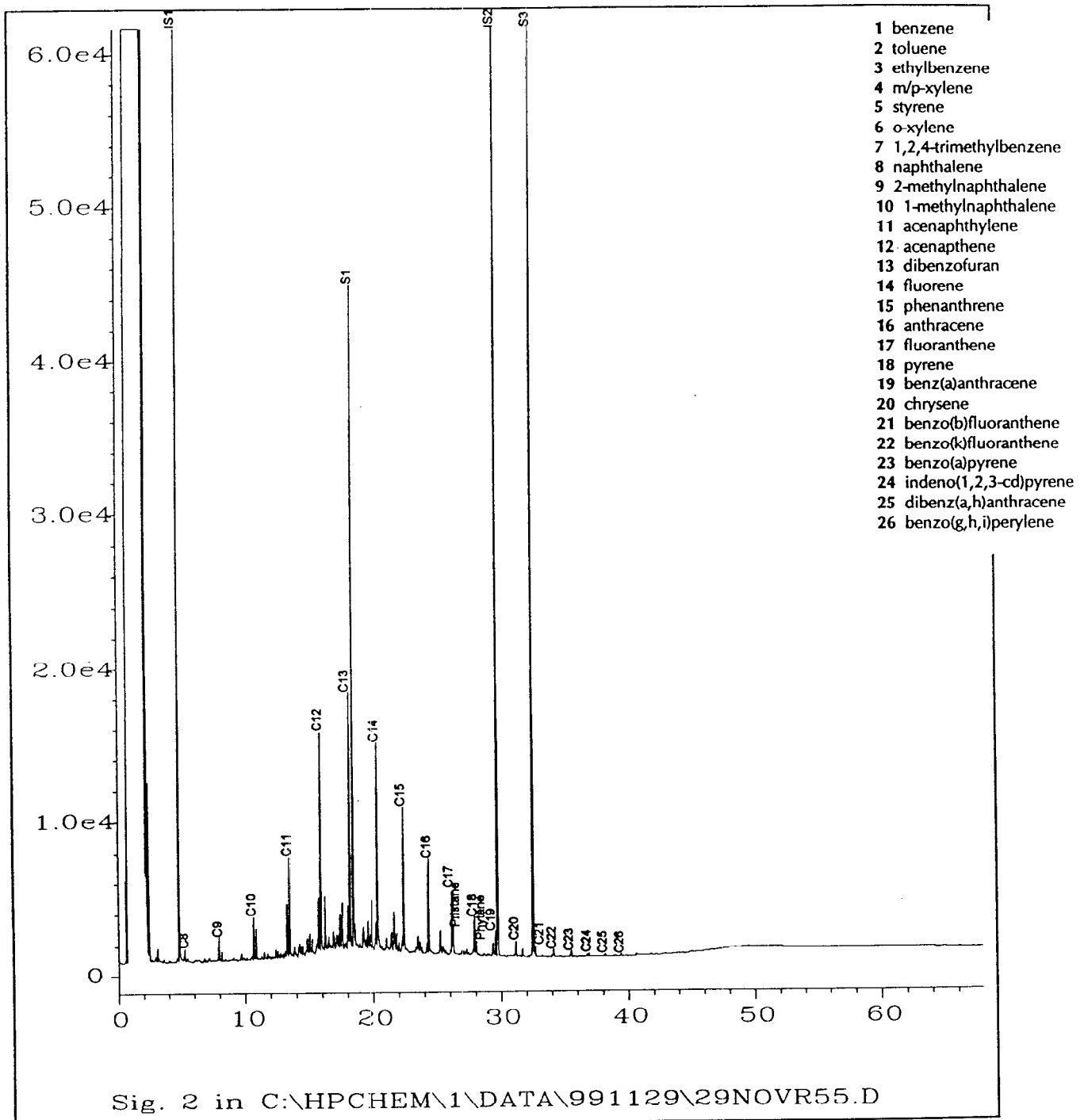
GC/FID Fingerprint



IS1 - 2,4-difluorotoluene
IS2 - o-terphenyl
S1 - fluorobenzene
S2 - 2-fluorobiphenyl
S3 - 5a-androstane

Field ID: **EW-1**
Laboratory ID: **IG991123-01UF**
Method: **MET4007D**

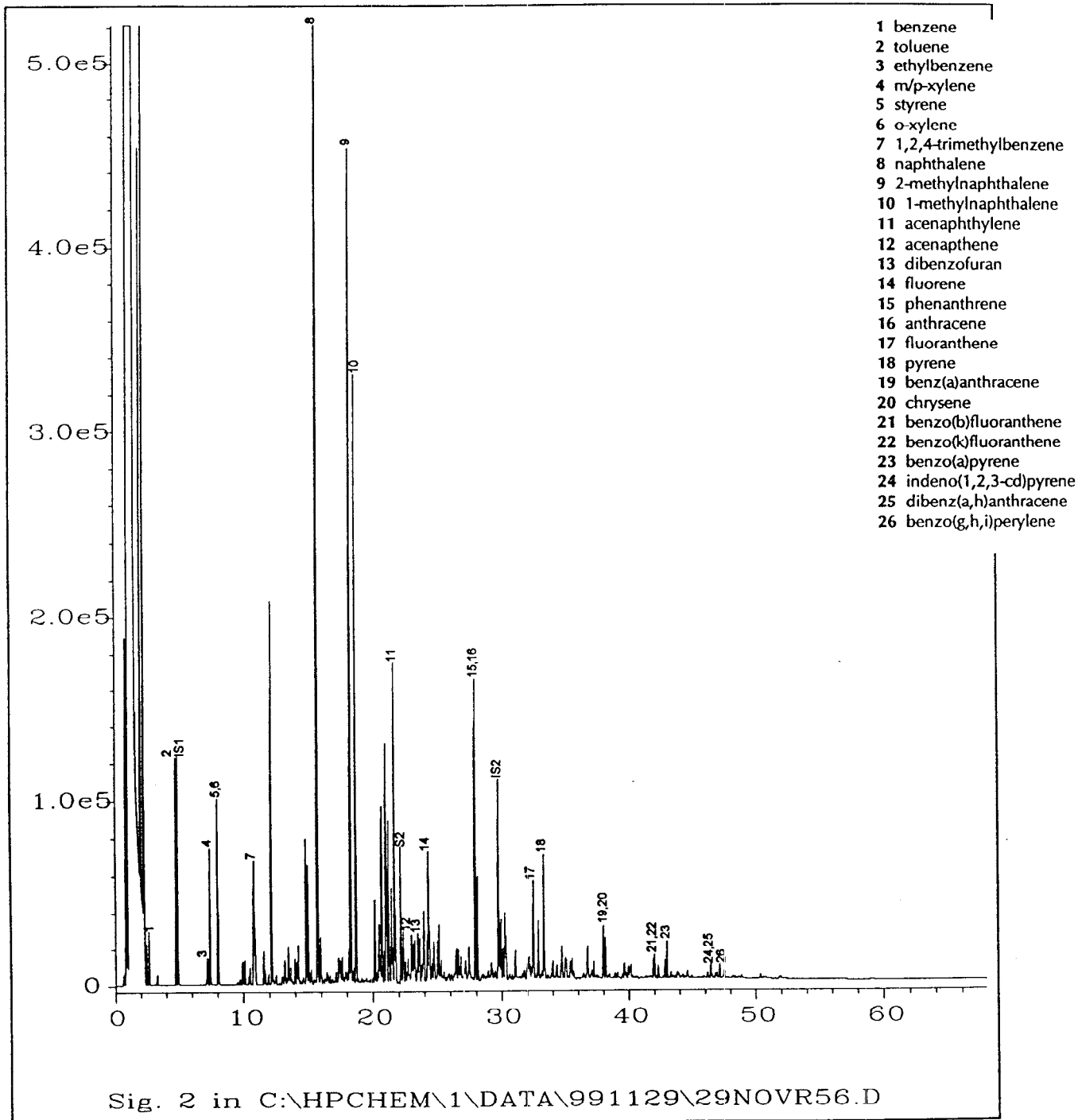
GC/FID Fingerprint



IS1 - 2,4-difluorotoluene
IS2 - o-terphenyl
S1 - 2,5-dibromotoluene
S2 - 2-bromonaphthalene
S3 - 1-chlorooctadecane

Field ID: **EW-1**
 Laboratory ID: **IG991123-01PF**
 Method: **MET4007D**

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene

IS2 - o-terphenyl

S1 - 2,5-dibromotoluene

S2 - 2-bromonaphthalene

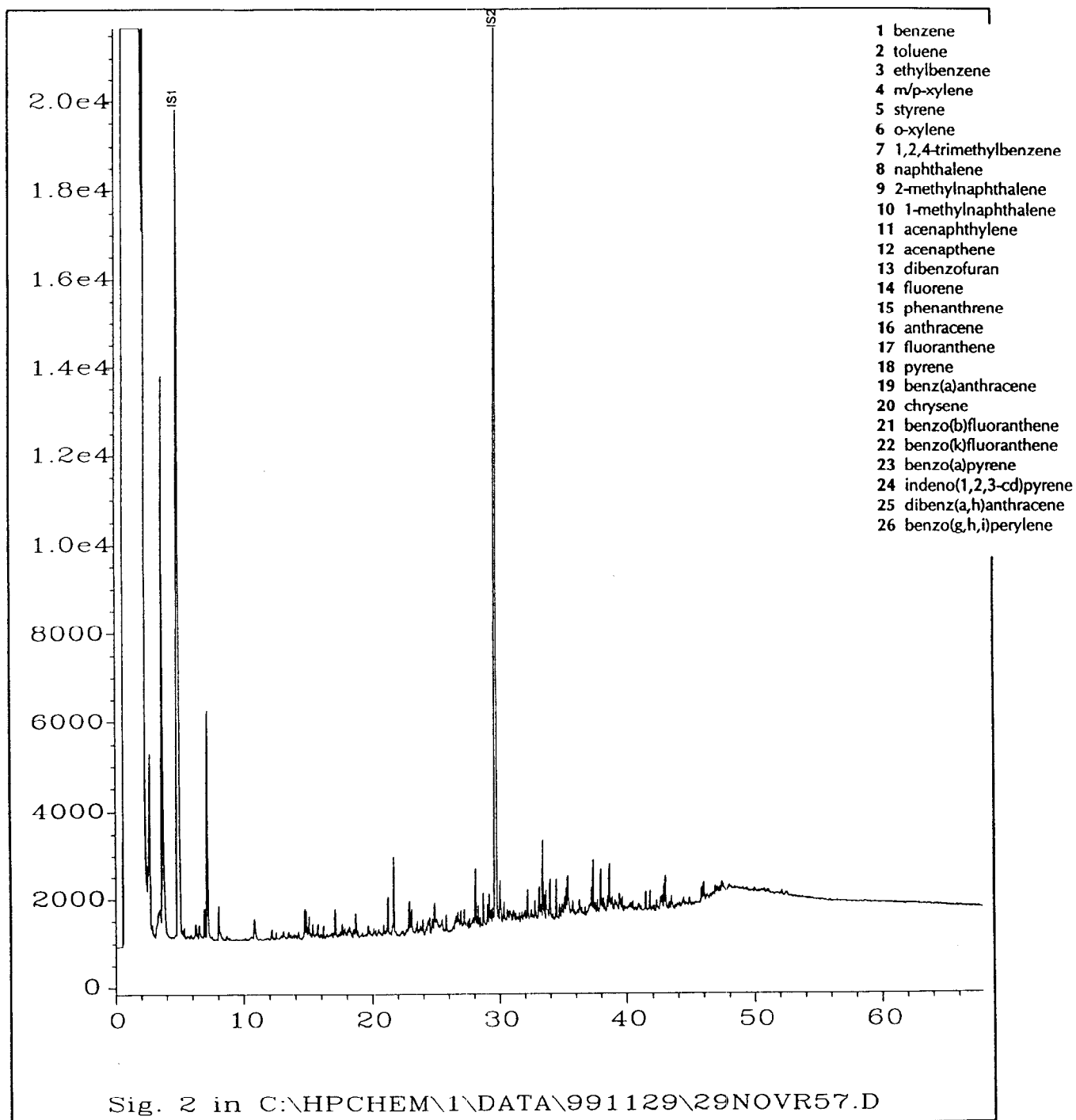
S3 - 1-chlorooctadecane

Field ID: **EW-1**

Laboratory ID: **IG991123-01DF**

Method: **MET4007D**

GC/FID Fingerprint



IS1 - 2,4-difluorotoluene

IS2 - o-terphenyl

S1 - 2,5-dibromotoluene

S2 - 2-bromonaphthalene

S3 - 1-chlorooctadecane

Field ID: EW-1

Laboratory ID: IG991123-01MF

Method: MET4007D

PROJECT NAME NISP. ASHLAND

COMPANY NSP - IGT - Domest & Intern

PHONE 1

SAMPLED BY Mark McEllen

(Print Name)

(Print Name)

(Print Name)

Signature

Signature

Signature

META 

Environmental, Inc.

49 Clarendon Street
Watertown, MA 02172
TEL: (617) 923-4662
FAX: (617) 923-4610

[illegible]

Date/Time

Received by

Relinquished by

Date/Time

Received by

Relinquished by

Date/Time

Received by

Relinquished by

Date/Time	
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Received for Laboratory by

Method of Shipment

Remarks:

* samples received @ 5.3°C

PROJECT NAME NSP - Ashland
COMPANY NSP c/o James & Moore
ADDRESS 25 Kessel Court Suite 201
PHONE (608) 273-2886

Signature _____

Signature _____

Signature _____

META  **Environmental, Inc.**

49 Clarendon Street
Watertown, MA 02472
TEL: (617) 923-4662
FAX: (617) 923-4610

[illegible]

APPENDIX C

RESUMES OF IGT PERSONNEL

DIANE L. SABER, Ph.D

EDUCATION

Post-Doctoral Associate, Yale University, New Haven, CT., Feb.-Dec. 1987
Principle Investigator, Prof. L. Nickolas Ornston.

Ph.D., Microbiology, University of Minnesota, Minneapolis, MN., Feb. 1987
Advisor, Prof. Ronald L. Crawford.

M.B.A. in Marketing, Fairleigh Dickinson University, Rutherford, New Jersey. Completed 50 of 60 credits. 1979-1981.

B.A., *cum laude*, Biology, Macalester College, St. Paul, Minnesota, 1978.

PATENT

Patent - #4,713,340 - Biodeterioration of Pentachlorophenol

TECHNICAL SOCIETIES

American Society for Microbiology
International Society for Biodeterioration
Hazardous Waste Treatment Council
Hazardous Waste Action Coalition
Illinois Association of Environmental Professionals
Biotechnology Industry Organization (BIO)

APPOINTMENTS

Co-Chair, Environmental Section - Biotechnology Industry Organization, 1995-present
Co-Chair, Environmental Biotechnology '96 Conference sponsored by BIO, June, 1996
Co-Chair, Pollution Prevention Symposium, Northwestern University, Center for Biotechnology, June 1996
Bioremediation Action Committee (BAC) under Administrator Reilly - Steering Committee; Treatability Study and Pollution Prevention Subcommittee 1990 - 1994.
Chairman - EPA BAC Bioremediation Workshop, Washington, D.C., February 1990
Adjunct Associate Professor, Universities of California - Irvine and Los Angeles, 1990-1991.
Instructor - "Groundwater Monitoring Protection and Cleanup" Winter Course, UCLA Extension, 1991.
Appointment - Hazardous Substances Control Engineering Research Center, University of California, Los Angeles, 1990-1991.
Appointment - Peoples to Peoples International Delegation for Biotechnology, Established by President Eisenhower, 1993.
Appointment - National Bioremediation Representative for the Hazardous Waste Treatment Council, 1990-1994.
Appointment - Biological Pollution Prevention Representative, AgBiotech Center, Rutgers University, 1992
Participant - EPA/DOE Innovative Technology Matrix Workshop; Bioremediation Expert, 1992.
Lecturer - Universities throughout United States, Europe, and Asia.

SUMMARY OF PROFESSIONAL EXPERIENCE

Over 18 years of experience in biotechnology applications to environmental restoration and pollution prevention. Senior Project Manager for over 10 years. Technical Lead for over 10 years. Projects range in size from Superfund cleanups to Phase I site characterizations.

Specific expertise in the isolation, adaptation and use of indigenous bacteria/fungi for toxic waste treatment, pollution prevention and biotechnology. Especially familiar with the removal of chlorinated pesticides and herbicides, and petroleum hydrocarbons from waste streams using ex situ, in situ and technology train approaches. Elucidation of intermediates of specific compounds based on microbial action under aerobic/anaerobic conditions a primary directive. Supervised and participated in design and implementation of in situ and above-ground systems for soil and groundwater treatment. Designed remediation programs which incorporate bioremedial systems with a variety of innovative technologies for clean-up, including air sparging, solidification, thermal treatment, chemical treatment, soil vapor extraction and combined technology approaches. Very involved in biological applications for pollution prevention. Co-founded a bioremediation company in 1982.

SENIOR BIOREMEDIATION SCIENTIST/PROJECT MANAGER, INSTITUTE OF GAS TECHNOLOGY, 1995-PRESENT

Project Management and technical advisor on projects dealing with combined technology approaches to site remediation, including biological/chemical treatment; treatability studies and field studies; laboratory research and reporting; marketing.

REPRESENTATIVE PROJECTS

PROJECT MANAGER, NiCor Company, Naperville, IL

Responsible for all tasks, schedules and deliverables associated with preparation of the conceptual design and implementation of IGT's MGP-REM process for remediation of soils at this former MGP site. This Phase III project included review and integration of Phase I and Phase II treatability study data.

BIOREMEDIATION TECHNICAL DIRECTOR, FLUOR DANIEL ENVIRONMENTAL SERVICES DIVISION, 1990 - 1994

Bioremediation Technical Lead, Principal Scientist and Project Manager for large-scale bioremediation projects internationally for both private and government clients.

Functional Leader for the design, implementation and evaluation of biologically-based technology systems for soil and water clean-up: in situ and above-ground designs. Responsible for critical input and evaluation of proposed remediation projects, integration of bioremedial processes with other cleanup technologies, elucidation of intermediates to compounds based on microbial action, direction of laboratory studies for the isolation and characterization of selected bacterial strains for degradation, analysis of biophysical/biochemical laboratory data for program optimization, evaluation of biological applications in tandem with other innovative and traditional remedial technologies, design of field studies for an integrated approach to remediation, full design, start-up, monitoring and review of existing bioremedial systems for both hazardous waste treatment and pollution prevention, and liaison between Fluor Daniel and universities, clients, private institutions, and companies involved with bioremediation and pollution prevention technology.

Responsible for business development activities including review and selection of subcontractors for teaming and prospective bioremediation projects. Direct knowledge of key companies and individuals in this industry.

REPRESENTATIVE PROJECTS

TECHNICAL LEAD, Ninth Avenue Program, Gary, Indiana

Responsible for all tasks, schedules and deliverables associated with selection and implementation of the Final Site Remedy (FSR) Plan for the CERCLA site heavily contaminated with chlorinated pesticides and solvents. These tasks include oversight of the risk assessment, preparation and selection of appropriate subcontractors for performance of laboratory-scale treatability studies modeling in situ bioremediation/soil flushing, soil washing, low temperature thermal desorption technologies and incineration technology, oversight of all treatability studies, oversight of design and performance of groundwater models associated with oil recovery (ARMOS) and in situ bioremediation/soil flushing programs (BIOPLUME), design and oversight of pilot scale testing of in situ or above-ground remedial technologies leading into full design and implementation of the FSR action plan.

Responsible for the Oil Recovery/Sequence Batch Reactor Interim Site Remedy (ISR) Program. Technical input and oversight of treatability studies pertaining to the optimal design and operation of all units associated with this program, oversight of final design preparation, oversight of procurement of associated equipment and instrumentation, oversight of subcontractors during start-up phase, technical assistance during start-up, oversight through end of ISR phase of oil recovery and groundwater treatment, and ongoing technical assistance pertaining to biological treatment during this phase (soil remediation program concurrent with groundwater treatment).

PROJECT MANAGER, Visalia Pole Yard Superfund Site, Visalia, California

Responsible for all tasks associated with the feasibility phase a CERCLA site contaminated with chlorinated pesticides, including bioremediation treatability studies focusing on in situ design, treatability studies using other innovative technologies, analysis of cost and implementation of all investigated technologies, studies and analysis pertaining to design of the in situ remedial action program, analysis of risk associated with each proposed design for remediation, pilot-scale testing of in situ technologies and design, analysis and testing pertaining to full design.

TECHNICAL LEAD, Clovis Superfund Site, New Mexico

Technical review and interface with EPA for application of bioremediation technology (land treatment design) for this site contaminated with chlorinated pesticides. Critical review and oversight of treatability studies, pilot scale testing and full design.

TECHNICAL LEAD, North Cavalcade Superfund Site, Texas

Technical oversight and engineering evaluation of bioremediation pilot scale testing, full-scale design and proposed full-scale program for this site contaminated with chlorinated pesticides.

TECHNICAL LEAD, South Cavalcade Superfund Site, Texas

Technical oversight of pilot scale testing program for analysis of design, review of pilot scale results and recommendation for final remedial design and implementation for cleanup of chlorinated pesticides. Bioremediation technology emphasized.

TECHNICAL LEAD, Confidential Client

Provided feasibility studies, treatability studies and engineering evaluation for a pentachlorophenol-contaminated site. Studied and analyzed options pertaining to in situ and above-ground clean-up of this PCP site. Included treatability and pilot scale testing of bioremediation designs.

TECHNICAL LEAD, Atlas Powder, Tamaqua, Pennsylvania

Technical oversight and direction of treatability studies/engineering evaluation associated with bioremediation of ammonium nitrate-contaminated slurry pits. Results will lead to full-scale design and construction of an above-ground bioremediation program, including a soil washing pretreatment followed by a 2-step nitrification/denitrification.

PROJECT MANAGER, ALCOA, Pittsburgh, PA

Responsible for complete environmental policy review and site investigation for a proposed factory expansion in Kuala Lumpur, Malaysia.

PROJECT MANAGER, Fluor Daniel "GET" Council, Irvine, California

Internally funded (\$300,000) project for the review, assessment, compilation, and documentation of all currently available remediation technologies. Resulting document was over 700 pages in length.

TECHNICAL SUPPORT, FERNALD Operable Units I and XII, Fernald, Ohio

Assisted in technical review of Feasibility Study associated with each of the Operable Units at the site. A wide variety of remedial options were utilized and incorporated.

PRINCIPAL ENVIRONMENTAL SCIENTIST, EBASCO ENVIRONMENTAL SERVICES, 1989 to 1990

Responsible for technical review and project management of bioremediation projects and integrated remedial programs, using innovative and traditional cleanup technologies. Work was with governmental Superfund, REM III and ARCS contracts in EPA regions IV, VI and IX. Working closely with the EPA and chaired bioremediation workshops on the use of "technology trains" for cost-effective and timely clean-up programs.

REPRESENTATIVE PROJECTS**PROJECT MANAGER, EPA Superfund REM III Project, Coleman Evans Wood Preserving, Florida**

Project included review and testing of bioremediation and solidification/stabilization technologies for selection in the Record of Decision (ROD) for soil remediation of this chlorinated pesticides site. This included a detailed literature review of the technologies leading to a Feasibility Study. Technical bid specifications were prepared and representative vendors were selected to perform 3 month bench top treatability studies. Success of the treatability studies were evaluated against clean-up criteria. The ROD prepared for the site details a combination approach using both technologies for clean-up of soils.

PROJECT MANAGER, EPA Superfund REM III Project, Whitehouse Waste Oil Pits, Florida

Project included review and testing of bioremediation and solidification/stabilization technologies for selection in the ROD for soil remediation at this site heavily contaminated with solvents, various organics and inorganics. This included a detailed review of the technologies leading to a Feasibility Study. Technical bid specifications were prepared and representative vendors were selected to perform treatability studies. Success of the treatability studies were evaluated against clean-up criteria.

TREATABILITY STUDY TECHNICAL LEAD, Rocky Mountain Arsenal, Colorado

Directed specific tasks relating to degradation of chlorinated pesticides and herbicides at this heavily contaminated site. Bench-top treatability studies performed, data collected, technology train approaches to cleanup evaluated. Specific recommendations were input to the Feasibility Study for the specific site areas.

TREATABILITY STUDY TECHNICAL LEAD, EPA Superfund REM III Project, Waste Disposal, Inc., California

Technical lead for testing of candidate technologies as they apply to soil and water cleanup of this site heavily contaminated with chlorinated pesticides, herbicides, solvents and inorganics. Results of the studies were included in a final Feasibility Study report to EPA, leading to a ROD for site remediation. Bid specifications were prepared for each technology and vendors were selected.

BIOREMEDIATION TECHNICAL LEAD, EPA Superfund REM Project, North Cavalcade Site, Texas

Conducted and led detailed treatability and pilot-scale testing on an in situ design for soil and water clean-up, leading to full process design specifications. Site contaminated with chlorinated pesticides.

BIOREMEDIATION TECHNICAL LEAD, EPA Superfund ARCs Project, American Creosote Site, Florida

Full design specifications from treatability study and pilot-scale testing of an integrated biological treatment unit for soil and water decontamination. Site contaminated with chlorinated pesticides.

MARKETING MANAGER AND BIOREMEDIATION CONSULTANT, CUSTOM AND RESEARCH AND DEVELOPMENT, LONDON, ENGLAND (1988)

Full-time consultant to a small European-based biotechnology company. Coordinated research and development projects in the area of bioremediation between university consortia nationwide and companies seeking to expand or enhance their technologies in hazardous waste treatment. Efforts focused on supplying and funding research in this area at the university level by identifying interested companies worldwide. Participated in company fundraising, writing of business plans and proposals, and international marketing.

TECHNICAL SALES REPRESENTATIVE, UNION CHEMICAL, NEWARK, NJ(1978 to 1981)

Responsibilities included product development, testing and marketing (competitive pricing, technical reporting, interfacing with customers and technical staffs), reformulation and evaluation of products, quality control, assessment of new potentials and expansion of markets, educating and directing customers in hazard waste management and disposal. Managed over 50 accounts, revenues totaled 2 million dollars annually.

THESIS TOPIC

Conducted research in the degradation of the biocide pentachlorophenol (PCP) by a naturally-occurring soil bacterium. Isolated and characterized particular Flavobacterium strains able to fully metabolize PCP compared these strains with respect to their degradative efficiency. Investigated biophysical and biochemical parameters which influence degradation rates and biomass production.

Planned and executed an on-site bioremediation project at a wood treatment facility using a soil washing/bioreactor system. Solicited funds from outside the university for further research and development of the technology. After continued improvement of the system through field trials, negotiated an agreement with a venture capital group for the establishment of a company based on bioremediation of PCP contaminated soil and water (1982). Patented the process - "Deterioration of Pentachlorophenol."

Directed research in the genetics of PCP degradation -- defining the genetic elements responsible for the ability to metabolize PCP and degradative plasmid studies using the Flavobacterium strains.

PUBLICATIONS

Saber, D.L. (1997). Site Remediation *in* Standard Handbook in Hazardous Waste Treatment and Disposal. McGraw-Hill, Inc., H. M. Freeman, ed.

Saber, D.L. (1996). Novel Wastewater Treatment Processes. Proc. HAZMAT Internatl. (Atlantic City, NJ, June 17-20).

Saber, D.L. (1995). Hierarchy of Treatability Studies for Assured Bioremediation Performance. Proc. Third Internatl In Situ and On-Site Bioreclamation Symp. (San Diego, California, April 24-27). 3(5):157.

Saber, D.L., Smith, J.R., Lawrence, A.W., and Middleton, AC, (1992). Optimization of an Oil Recovery/Groundwater Treatment System Based Upon Treatability Study Testing/Engineering Evaluations for a Superfund Site. Abstract. AICHE Summer Meeting (Minneapolis, Minnesota, August 9-12).

Saber, D.L., Smith, J.R., Lawrence, A.W., and Middleton, AC, (1992). Sequencing Batch Reactor Treatment of Superfund Site Groundwater. Abstract. Proc. 65th Annual Conference, Pol. Conf. Fed. (New Orleans, LA, September 20-24).

Montazer, P., Van de Water, J.G., Saber, D.L., and Bull, L. (1992) Evaluation of Removal of Free-Phase and Dissolved Petroleum Hydrocarbon Constituents From an Uncontrolled Hazardous Waste

Site. Abstract. Petroleum Hydrocarbon and Organic Chemicals in Groundwater: Prevention, Protection and Restoration Conference. (Houston, Texas, November 4-6).

Saber, D.L., and Crawford, R.L. (1985). Isolation and Characterization of Flavobacterium Strains That Degrade Pentachlorophenol. Appl. Environm. Microbiol. 50:1512-1518.

Saber, D.L., and Crawford, R.L. (1985). Isolation and Characterization of Pentachlorophenol-Degrading Flavobacterium Strains. Abstract. Proc. 85th Annual Meeting Am. Soc. Microbiol. (Las Vegas, Nevada, March 3-7). Poster Q23.

Saber, D.L., and Crawford, R.L. Characterization of Pentachlorophenol-Degrading Flavobacterium Strains: Biophysical and Biochemical Comparison of Six Representative Strains.

Saber, D.L., and Crawford, R.L. Genetics of Pentachlorophenol Degradation by Flavobacterium Strains: Evidence for Possible Plasmid Involvement.

Saber, D.L., and Ornston, L.N. Introduction and Maintenance of Plasmid pUC19 in Acinetobacter calcoaceticus.

Martinson, M.M., Steiert, J.S., Saber, D.L., and Crawford, R.L. (1984). Microbial Decontamination of Pentachlorophenol-Contaminated Natural Waters. Proc. 6th Int. Biodet. Symposium (Washington, D.C., August 5-10). Commonwealth Agricultural Bureaux, London, England.

Marshall, J.S., Mellinger, D.L., and Saber D.L. (1978). Experimental Studies of Stress in Freshwater Plankton Communities Using Different Enclosure Techniques. Abstract. Proc. 41st Annual Society Limnol. Oceanogr. (Victoria, B.C.).

Marshall, J.S., Mellinger, D.L., and Saber, D.L. (1977). Effects of Cadmium on a Lake Michigan Plankton Community. Radiological and Environmental Research Division Annual Report, January-December, ANL-77-65, Part III, 59-64.

Marshall, J.S., Saber, D.L., and Mellinger, D.L. (1977). Effects of Enclosure on a Lake Michigan Zooplankton Community. Abstract. Proc. Int. Ass. Great Lakes Res.

Papers presented at technical conferences available upon request.

Thomas David Hayes

Gas Research Institute
8600 W. Bryn Mawr Ave.
Chicago, IL 60631
Thayes@gri.org

SUMMARY OF EXPERIENCE

SENIOR ENVIRONMENTAL ENGINEER with extensive experience in governmental and industrial environmental research and development (twenty years), environmental regulation (three years), and consulting in site remediation.

- Technical expertise in physicochemical-biological systems design and control for the management of groundwater, wastewater, solid waste, sludges, and hazardous wastes.
- Experienced in managing energy and environmental research programs totaling more than \$4 million per year in gas industry funds and \$5 million per year in funds obtained from state, federal and other industrial sources.
- Developed and commercialized novel processes for improved conversion of biomass and waste to environmentally-friendly fuels.
- Public Health Specialist in three health departments with wide range of regulatory experience in water supply, community waste management, housing control, food service, wastewater treatment, and industrial waste management.
- Over 16 years of experience in organizing and directing multidisciplinary teams of scientists and engineers to bring existing and emerging technologies to bear on resolving site remediation problems and opening new market opportunities for the natural gas industry.
- Successfully completed over 25 field demonstrations of advanced remediation technologies that produced significant savings to the natural gas industry.
- Author of over 70 publications and 5 patents.
- More than 13 years of experience in the coordination of manufactured gas plant (MGP) R&D.
- Internationally-recognized expert in innovative, risk-based approaches to contaminated site management.
- Edited a comprehensive two-volume guidebook on MGP site management which is used throughout the natural gas industry
- Coordinated the GRI/EPRI MGP Seminar for the past decade.
- Advisor to numerous national conferences on environmental site management.
- Developed excellent cooperative relationships with the oil & gas industry.
 - Performed consulting and technology applications projects for utilities as a part of the GRI/IGT Alliance called "Site Management Solutions"
 - Led remediation technology workshops for regulators in eleven states
 - Successful track record in regulatory negotiations

EDUCATION

Ph.D. Environmental Engineering (C.E.), University of Notre Dame
M.S. Environmental Engineering (C.E.), Purdue University
B.S. Public Health, Indiana University, Graduated with honors.

PUBLICATIONS

Over seventy publications to date, including the open literature, U.S. Government

Documents, and Books. Complete listing available upon request.

PATENTS

Combined Biological-Chemical Detoxification of Sewage Sludge, T.D. Hayes and W.J. Jewell, Patent 4,277,342 (1982).

Chemical Detoxification of Sewage Sludge, T.D. Hayes, W.J. Jewell, and R.M. Kabrick, Patent 4,370,233 (1983).

Production of High Methane Content Product By Two Phase Anaerobic Digestion T.D. Hayes, H.R. Isaacson, and J.R. Frank, Patent 4,722,741 (1988).

Solids Concentrating Reactor, D. Chynoweth, V. Srivastava, R. Biljetina, and T.D. Hayes, Patent 4,735,724 (1988).

A Method of Utilizing Foams for the In-Situ Remediation of Soils and Groundwater T.D. Hayes, Submitted Disclosure to U.S. Patent Office (1995).

ORGANIZATION MEMBERSHIPS

Registered Environmental Health Specialist in the State of Indiana; Association of Environmental Engineering Professors; Sigma Xi.

WORK EXPERIENCE

Current Employer **GAS RESEARCH INSTITUTE, CHICAGO, IL**

1993-Present

Principal Technology Manager, Site Remediation

Leader of GRI's Site Remediation Programs. Coordinated large programs on the development of advanced, cost-effective treatment technologies for the gas industry. Working in a business alliance with the Institute of Gas Technology (IGT) called "Site Management Solutions" to apply a wide range of technologies in the cleanup of industrial contaminated sites.

Recent Accomplishments

- In collaboration with IGT and other commercial partners, achieved substantial savings in the remediation of utility sites, averaging more than \$1 million per site
- Completed over twenty five field demonstrations in eleven states with the involvement of fifteen gas companies, four commercial partners and five non-gas industry funding organizations, including EPRI, DOD, DOE and the USEPA Superfund Sites Program. The technologies that were evaluated included:
 - Chemical-biological treatment (soil at MGP and wellhead sites) using several modes:
 - ❖ Engineered Land Application
 - ❖ Bioslurry
 - ❖ In-Situ (in-place in the subsurface of a site)
 - Fluidized bed reactor (BTEX in groundwater & produced water)
 - Methanotrophic Treatment (TCE in groundwater)
 - Soil Cofiring with Coal in Utility Boilers
 - Freeze-Thaw-Evaporation Demineralization (produced water)
 - Contained Recovery of Oily Waste (CROW) (MGP)
- Achieved treatment cost reductions of more than 70% with the

commercial deployment of advanced site remediation technologies including the fluidized bed reactor for water treatment and chemical-biological treatment of soils (in the bioslurry, land treatment, and in-situ modes).

- Pioneered new in-situ remediation concepts including foam remediation.
- Led a national research program for the development of a scientific basis for alternative environmentally acceptable endpoints (EAE) for site remediation. This effort involved the participation of many organizations associated with academia, industry, and government at the state and federal levels.
- Developed tools for contaminated site management
 - Probabilistic Cost Model based on Monte Carlo Decision Tree Analysis
 - Database for multiple site management
 - Engineering decision guidance manuals (Land Treatment, Bioslurry, Gas Holder Removal, Fluidized Bed Reactor Applications, etc.)
- Total future benefits to the gas industry of remediation products and tools estimated at more than \$240 million over the next 10 years

1990-1993

Senior Project Manager, Environmental Engineering

- Managed remediation R&D programs for the gas industry including GRI's Manufactured Gas Plant Program, the Gas Supply Remediation Program, and Produced Water Management Program.
- Coordinated engineering systems analyses as an aid to the gas industry in quantifying benefits to industry, prioritizing R&D, and tracking progress in development and commercialization.

1986-1990

Coordinator for Biotechnology Applications in GRI's Basic Research Program

- Developed new methanotrophic processes that destroy chlorinated hydrocarbon pollutants in groundwater.
- Managed basic research on the use of chemical pretreatment that accelerated the rates of PAH and PCB pollutant biodegradation in soils by five to ten times.

1982-1986

Project Manager, Waste Management and Biomass Technologies

- Managed the waste-to-methane project at Walt Disney World and successfully demonstrated an integrated, pilot-scale, aquaculture/anaerobic digestion system that was capable of reducing secondary treatment costs by 25 percent.
- Managed a large, national, biomass-to-methane R&D program which included University of Florida, Texas A&M, Cornell University, and the Institute of Gas Technology. Breakthroughs in genetic engineering of crops and process engineering reduced methane generation cost from

\$13 down to \$5/mmBtu.

- Successfully developed of integrated systems that substantially improve the cost of producing energy from biomass and waste.

1980-1982

BATTELLE LABORATORIES, COLUMBUS, OH

Research Scientist

- Participated in a number of research projects related to hazardous waste disposal, wastewater treatment and fuels from biomass. Examples:
- Evaluated oil agglomeration and flotation to recover coal fines from blackwater generated in mining operations. Improvements were made that cut oil dosage requirements and significantly reduced operating costs.
- Applied landfarming bioremediation to the treatment of oil/uranium wastes.
- Developed sampling protocol for BZ nerve agent site characterization at a major military facility located at Pine Bluff, Arkansas.
- Designed processes for military waste decontamination using UV/oxidation systems capable of destroying chemical warfare agents in wastewaters.

1976-1980

CORNELL UNIVERSITY, ITHACA, NY

Research Associate

- Coordinated a team of research staff and professors for a large DOE-funded research effort to develop anaerobic fermentation process designs for the conversion of agricultural wastes to methane. This program was successful in identifying two low-cost, efficient reactor designs that could be easily integrated into small farm operations.
- Identified an effective, low-cost method for the removal of cadmium and other heavy metals from sewage sludge; highly successful laboratory experiments formed the basis for two patents. This work addressed some critical issues in the land disposal of sewage and industrial sludges.

1973-1974

ELKHART COUNTY HEALTH DEPARTMENT, ELKHART, IN

Public Health Specialist

Responsibilities included supervision of the county food service inspection program, inspections of landfills, housing and public swimming facilities, design and inspection of private residential sewage systems and private water supplies and the conduct of water pollution surveys around the county's lakes.

Summer of 1971

LAPORTE COUNTY HEALTH DEPARTMENT, LAPORTE, INDIANA

Public Health Specialist

Rural and urban public health work, similar to Elkhart County Health Department experience.

Summers of 1968-

HILLSDALE COUNTY HEALTH DEPARTMENT, HILLSDALE, MICHIGAN

1970

Public Health Specialist

Rural and urban public health work, similar to Elkhart County Health Department experience.

ANALYTICAL RESULTS
MAHs and PAHs
Client: IGT Project: I05001

Lab ID	IG991110-01	IG991110-02
Field ID:	MW-7	MW-15
MAHs:		
Benzene	398	900
Toluene	77.7	4,190
Ethylbenzene	1,030	1,590
m/p-Xylene	982	4,460
Styrene	149	1,050
o-Xylene	761	2,170
1,2,4-Trimethylbenzene	2,130	2,930
Total MAHs:	3,390	14,400
PAHs:		
Naphthalene	32,700	58,300
2-Methylnaphthalene	24,200	20,600
1-Methylnaphthalene	25,900	11,000
Acenaphthylene	7,220	5,810
Acenaphthene	25,100	1,390
Dibenzofuran	4,650	811
Fluorene	9,310	3,440
Phenanthrene	26,800	14,300
Anthracene	11,200	4,090
Fluoranthene	9,140	4,660
Pyrene	13,300	7,000
Benz(a)anthracene	5,530	2,960
Chrysene	3,930	2,280
Benzo(b)fluoranthene	1,590	879
Benzo(k)fluoranthene	2,310	1,320
Benzo(a)pyrene	3,670	2,220
Indeno(1,2,3-cd)pyrene	1,310	879
Dibenz(a,h)anthracene	354	224
Benzo(g,h,i)perylene	1,500	999
Total PAHs:	205,000	142,000
Quantitation Limit:	52.1	45.5
Detection Limit:	20.8	18.2
Concentration Units:	mg/kg	mg/kg

B = Analyte detected in the blank

D = Values from a diluted sample extract

DL = QC compounds diluted out

E = Estimated value, above calibration range

I = Interference

J = Estimated value

L = Coeluted with compound listed above

NM = Not measured

U = Not detected at quantitation limit shown

Total MAHs does not include 1,2,4-Trimethylbenzene.

Total PAHs does not include Dibenzofuran.

All soil results reported on a dry weight basis.